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ARMSTRONG LABORATORY

50 YEARS OF HUMAN ENGINEERING

HISTORY AND CUMULATIVE BIBLIOGRAPHY OF THE FITTS HUMAN ENGINEERING DIVISION (U)

Edited by:
Rebecca J. Green
Herschel C. Self
Tanya S. Ellifritt

CREW SYSTEMS DIRECTORATE
HUMAN ENGINEERING DIVISION
WRIGHT-PATTERSON AFB, OHIO 45433-7022

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13. ABSTRACT *(Maximum 200 words)*

This report depicts the Human Engineering Division's research and development efforts spanning the past half-century. It is organized around a reference bibliography comprising technical reports, journal publications, conference proceedings, books and book chapters published between August 1945 and December 1994.

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FOREWORD

Engineers have been aware of the desirability of designing equipment to meet the requirements of the human operator, but in most cases have lacked the scientific data necessary for accomplishing this aim.

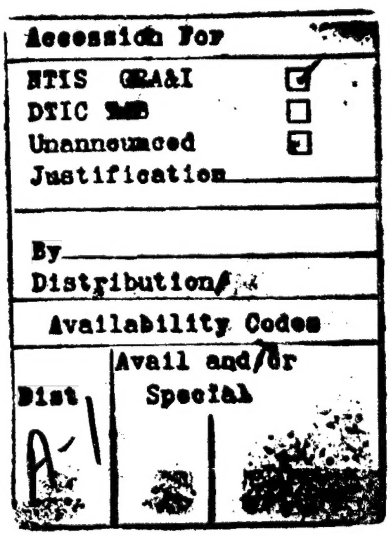
— P.M. Fitts

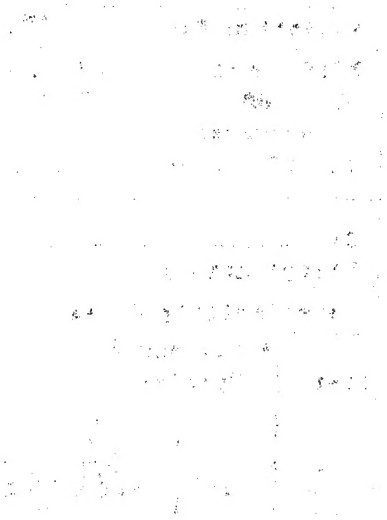
What is now the Fitts Human Engineering Division began with a directive for establishment of the Psychology Branch in the Aero Medical Laboratory at Wright Field in the closing days of World War II (May 1945). The mission of the Psychology Branch, under the leadership of Lt Col Paul M. Fitts, was the scientific study of human capabilities and characteristics that could be applied to the design of equipment, operations, and work environments. This was a significant event, the first organizational commitment to human engineering research and development undertaken within the United States military.

Successful military performance is dependent on the effective integration of human and systems technologies. Human-centered systems promote mission success through superior operability, maintainability, and survivability. The ultimate advantages of technological advances in controls, displays, and information handling, remain inextricably linked to human factors such as the pilot's sensory, perceptual, cognitive, and motor capabilities; strength and anthropometrics; motivation; experience; and skills. The mission of the Fitts Human Engineering Division is to ensure this linkage by anticipating future needs, developing human engineering technologies, and providing human-system integration design criteria to exploit the fullest potential of the Air Force warfighting team, irrespective of gender, mission, or environment.

Dr. Fitts' legacy of scientific excellence and relevance to military needs is embodied in five productive decades of research by the organization he founded. On this occasion — the fiftieth anniversary of the Fitts Human Engineering Division — we are proud to offer this volume which depicts the Division's research and development efforts spanning the past half-century.

JAMES W. BRINKLEY, SES
Director, Crew Systems





PREFACE

The data, models, guidance, technology demonstrations, and evaluations produced under laboratory research and development efforts are typically archived as technical reports, journal articles, or other professional communications. Ultimately, the scientific and technical documentation is the enduring product of research and development. In the normal course of events, however, collections of these technical information products accumulate and all too often languish in libraries, databases, and proprietary archives. Under these conditions, the value of research and development accomplishments and investments may either be diminished or never attained. Given that the value of information can only be realized through its use, it is therefore vital that responsible research and development managers make every effort to reduce the high costs of "rediscovery" of their research products by potential users.

The mission of the Armstrong Laboratory, Fitts Human Engineering Division involves the definition and documentation of capabilities and limitations of operators through scientific study of human behavior, physical characteristics, physiology, strength, performance, and tolerance of physical and mental stresses to aid the design of technologically superior human-systems. In developing this cumulative bibliographic reference, it was our intent to aid and promote the accessibility of relevant Human Engineering Division research information. Additionally, this commemorative volume is a celebration of five decades of human engineering research and development.

This volume is organized around a reference bibliography comprising the cumulative technical reports, journal publications, conference proceedings, books and book chapters documenting the research and development program of the Fitts Human Engineering Division from August 1945 through December 1994. The bibliography is divided into five sections or decades of activity and is organized alphabetically by author within each of these decades. The bibliography is itself generously illustrated with photos, illustrations, data functions, quotes, biographic notes, and period anecdotes which exemplify the people and events which have shaped the history and character of the division. The introduction includes several narrative histories and an optimistic nod towards the Human Engineering Division's future.

We sincerely hope that you enjoy this historic document. If you have further interest in the mission or products of the Fitts Human Engineering Division, please do not hesitate to contact me at:

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Kenneth R. Boff, PhD
Chief, Human Engineering Division

ACKNOWLEDGMENTS

No task of this magnitude is accomplished without the contributions of a large and diverse group of people. This project is certainly no exception. It is incumbent upon us, the editors of this document, to see that proper credit is given to the many dedicated and talented people whose efforts brought this project to a successful conclusion.

The inspiration for this document originated with the planned celebration of the 50-year anniversary of what is now called the Human Engineering Division. Located under the Crew Systems Directorate of the Armstrong Laboratory, the Human Engineering Division (AL/CFH) traces its roots to 1945 and the establishment of the Psychology Branch, Aero Medical Laboratory. The concept of producing a bibliography of all research published over 50 years by researchers in the Human Engineering Division and its predecessors is a natural one and is attributable to Dr. Kenneth R. Boff, currently Chief of the Human Engineering Division. Evolution of that concept into the broader, historically enhanced bibliography you see printed here can also be traced to Dr. Boff. It is safe to say that Dr. Boff was the creative and driving force behind this project. He gave us lofty goals to meet, high standards to guide us along the way, and the resources needed to succeed. To the extent that this document conveys the sense that Air Force human engineering for half a century has been both productive and fascinating, the credit goes to Dr. Boff.

Getting from decades-old partial bibliographies captured in various forms and formats to a cohesive 50-year bibliography was a triumph of both automation and brute force. Key to the success of this project was the technical and clerical support of employees of our engineering support services contractor, Logicon Technical Services, Inc. Leading the way was Susan Pfaadt, Software Department Manager. Susan waged a successful year-long campaign to develop a flexible database in which to store the 2,500-plus citations that represent the 50-year research throughput of the Human Engineering Division. She converted bibliographic inputs from WORDSTAR and other arcane bibliographic databases, managed the hand entry of citations when necessary, identified spurious data entries, and "ported" the finished data to a desktop publishing computer program. Susan went on to become a full member of the project team, and the editors wish to express their deep appreciation for her countless valuable suggestions regarding all aspects of the project.

Not the least of her contributions was Susan's hiring of a subcontractor to build the electronic copy of the bibliography in PAGEMAKER, a desktop publishing computer program. The young lady, Kimberly Kayler Izenson, proved to be another "hero" of this project. With a work ethic that left us in awe, Kimberly pulled together pieces from dozens of contributors and, in less time than we could imagine, laid out a tasteful, visually appealing, accurate document. It is important to note, also, that Kimberly was a frequent, valuable contributor of ideas for making improvements to this document. She was an emergent leader taking responsibility for facets of this project, such as scanning illustrations into the computer and single-handedly building an author index, for which she was not originally responsible. Her flexibility and enthusiasm were both welcome and fortuitous. Recognition is also due David Spangler of LTSI for a summer-long dedicated effort at keystroking citations into the computer database.

A project of this scope demands leadership to succeed. In each stage of this effort, leadership was passed to the project team member with the necessary skills to see that stage successfully through to completion. Special thanks, however, go to Walt Summers, Chief of the Ergonomics Analysis Branch, for his central role, largely during the late stages of the project, in pulling together parallel activities and focusing them toward completion. He skillfully walked the fine line between realizing the best product possible and getting the project done in a timely fashion. His quiet, understated manner was instrumental in facilitating the process of emergent leadership.

Many other major contributions to the success of the project came from members of the Ergonomics Analysis Branch of the Human Engineering Division. Renee Kaffenbarger, for example, stood as a skilled and willing typist and proofreader. Time and again, she keystroked valuable and historical documents into her word processor for inclusion in the bibliography. While the documents were often long, Renee's responses were always rapid, skillful, and congenial—she is a truly remarkable individual and a treasured resource. Early in this project, SSgt Wiley Wells, also of AL/CFHA, got us started in the graphics portion of the project by digitally scanning all the graphics selected for the book up to that time.

The gifted interviewing techniques of Dr. Reuben Hann were enlisted as part of this project to capture the recollections of key figures in the division's history. Lew's interviews with the likes of Dr. Melvin Warrick, Steve Heckart, Dr. Robert O'Donnell, Dr. Don Topmiller, and Charlie Clauser, add a warm, human touch to this work. Lew also extracted quotes from material gathered earlier in interviews with Earl Sharp and Phil Kulwicki. We thank him and the seven interviewees for their prompt and valuable participation. Dr. Ken Kennedy, whose interview was regrettably lost due to a recording difficulty, also deserves our thanks. In addition, our grateful acknowledgment is extended to Steve Heckart and Jean Ring for their generosity in contributing valuable early technical reports and articles from their personal collections.

Another contributor deserving of special recognition is Wayne Martin. A long-time member of the Human Engineering Division, who moved on to assignments elsewhere in the Crew Systems Directorate, Wayne generously contributed two anecdotes which give the reader valuable insight into life in the Human Engineering Division some decades back. Dean Kocian and Dr. Joe McDaniel of the Human Engineering Division deserve similar praise for their fascinating historical timelines of two key human engineering technologies. Dean's history of helmet-mounted device technology forcefully illustrates the central role played by the division in the development of the entire helmet-mounted sight, helmet-mounted display, night vision goggle, and virtual reality fields. Similarly, Joe McDaniel's history of workplace accommodation traces for the reader the long and rich history of yet another central facet of human engineering technology. Our grateful thanks go out to each of these authors for taking time during a particularly hectic time of year to provide these valued documents.

Help from outside the Human Engineering Division family should also be recognized. Mike Gallagher of the Defense Printing Service Detachment Office was particularly patient, participating in long meetings and taking numerous phone inquiries, all in the name of educating us in the complexities of printing a document of this nature. That he succeeded, in large measure, is credit to his skill and determination. Thanks are also extended to Klein Associates for sharing with us the results of interviews conducted with Earl Sharp and Phil Kulwicki. Though conducted for another purpose, the interviews provide delightful insights into long-standing and special relationships between the division and some of its "customers."

Valuable support was provided by administrators at several levels. Within the division, Randy Yates, of the Design Technology Branch, was a valuable source of information and help in setting up and using the computer hardware and software facilities required to do this job. Randy's support is particularly noteworthy given that the timing of our requests for support coincided exactly with the busiest time of year for Randy's other support commitments. Patricia M. Lewandowski, the Crew Systems Directorate STINFO (Science and Technology Information Officer), was also a source of crucial support to us in getting clearance of this document for public release, advice on publication procedures, and assistance in recovering bibliographic information from directorate files.

Proofreading, however painful, is pivotal in a project of this type. We had the good fortune on this effort of having some of the best proofreaders around on our team. Besides Kimberly Izenson herself, our proofreading corps included Elizabeth Combs and Anita Cochran. Betsy Combs, the current division secretary, suffered from work overload even without this proofreading assignment. But, that never stopped her before and it didn't this time either. The thoroughness and accuracy of Betsy's proofreading were incredible. One of the few proofreaders in Betsy's league is Anita Cochran. Anita is retired from the University of Dayton Research Institute and was available to us as a consultant through the Crew System Ergonomics Information Analysis Center, or CSERIAC. She performed the final edit on all parts of this document, including all citations, the list of illustrations, and the author index, always patiently waiting on us for material and then responding magnificently to our need for quick turnaround. Her comments and corrections were absolutely essential. She is amazing. An additional note of thanks goes out to countless contributors of ideas, photographs, text, corrections, etc., who cannot, for reasons of practicality, be cited individually here—your generosity is nonetheless noted and appreciated.

This brings us to our final acknowledgment. The editors wish to acknowledge the magnificent skill, knowledge, energy, enthusiasm, and dedication of the men and women of the Human Engineering Division, both past and present. The experience of compiling and editing this book drove home in unmistakable terms the staggering accomplishments of this merry band of human engineers. We have drawn freely from their lore in putting this document together. Exemplary of that group is Dr. Melvin Warrick, former Associate Division Chief of the Human Engineering Division. Mel was with the Human Engineering Division, then the Psychology Branch, in 1946, and he is still with us, as a volunteer, today. An invaluable resource for this project in terms of identifying people, facilities and programs from old-time documents, and verifying the historical accuracy of our entries, Mel represents the embodiment of the collective human engineering spirit—a proud, industrious, intellectual, and obviously well published scientific family.

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SECTION 1 - 50 YEARS OF HUMAN ENGINEERING: NARRATIVE HISTORY

I. ORGANIZATION, MISSION, AND GOALS

The Fitts Human Engineering Division is one of three research divisions within the Crew Systems Directorate of the Armstrong Laboratory, headquartered at Brooks Air Force Base, San Antonio, Texas (Figure 1-1). The mission of the Fitts Human Engineering Division is to enable or ensure the effective integration of humans with technology in USAF systems. Research and Development (R&D) is directed at boosting system performance and affordability by enhancing the operability, supportability, and survivability of these complex human systems. The scope of the R&D program encompasses three areas of regard:

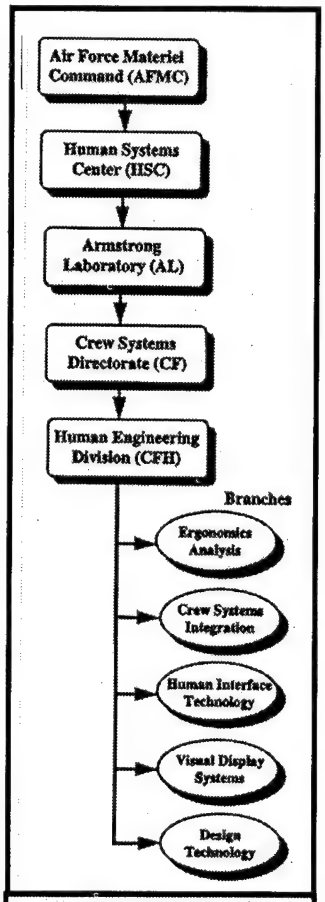


FIGURE 1-1: ORGANIZATIONAL CHART

(1) **Information Management & Display** develops methods and media to ensure reliable access to and decision making with task critical information by individuals, teams, and organizations;

(2) **Performance Aiding** produces innovative technologies for assisting operators and maintainers in performing their jobs more effectively, thereby minimizing human error while optimizing speed and quality of mission performance; and,

(3) **Design Integration** advances specialized databases, metrics, tools, and models of human capabilities and attributes to ensure that equipment designs support the fullest potential of warfighters, irrespective of gender, mission, or environment.

R&D in each of these technical problem areas may be conducted under the core program or as a rapid response to customer requirements. The latter activity, analogous to "fire-fighting," is characterized by short-suspense problem-solving "in the field" using the best data, knowledge, and skills that are readily available (Figure 1-2) . This activity has typically encompassed consulting and trouble-shooting of human factors problems with military equipment during design, integration, test and evaluation, and deployment or operations in varying stages of the acquisition process or in the field. Increasingly, this "fire-fighting" activity includes response to commercial industry, academia, local government, and other federal agencies. Most of these efforts are directly funded or cost-reimbursed by customers and, in recent years, have encompassed approximately 30 percent of the total activity of the division. This work has been especially vital to maintaining the relevance of our overall R&D program to USAF and military needs.

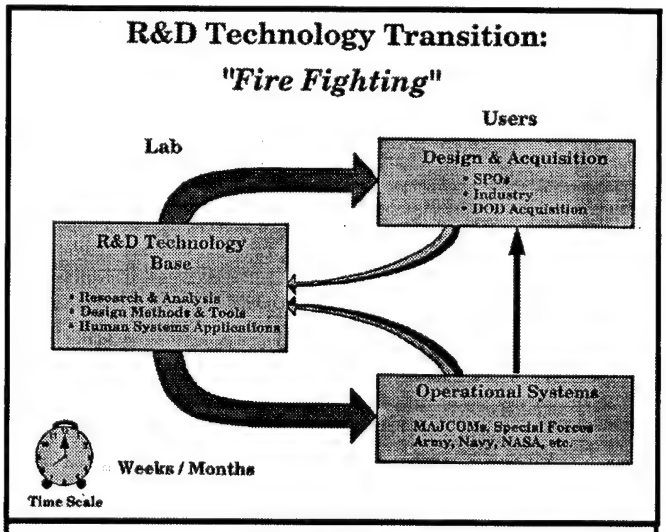


FIGURE 1-2: FIRE FIGHTING

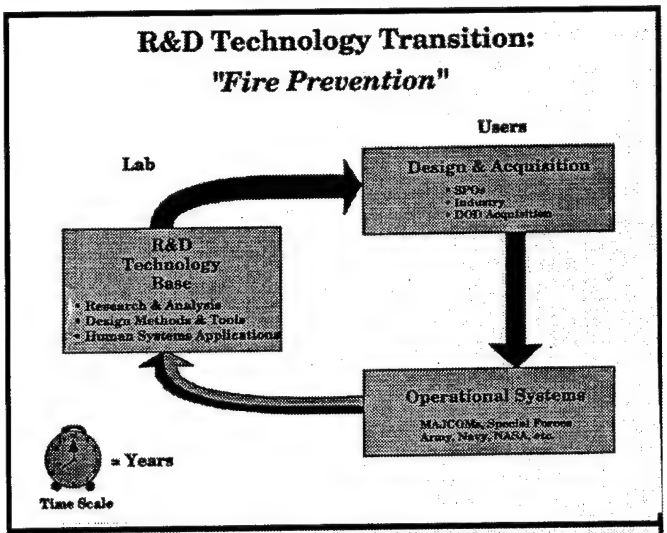


FIGURE 1-3: FIRE PREVENTION

Human Engineering Division Facilities

Design Technology Laboratories
- Behavioral Visualization Laboratory
- Crew-Centered Analysis and Design Support Laboratory (C-CADS)
- Computerized Anthropometric Research and Design Laboratories (CARD)
- Physical Ergonomics Laboratory (PEL)

Crew Systems Integration
- Multi-Operator Design Assessment Laboratory
- Crew Aiding and Information Warfare Analysis Laboratory (CIWAL)

Operator Assessment Technologies
- Cognitive Assessment Laboratory (CAL)
- Flight Psychophysiology Laboratory

Adaptive Interface Technologies
- Synthesized Immersion Research Environment (SIRE)
- Virtual Environment Interface Laboratory (VEIL)
- Fusion Interface for Tactical Environments (FITE)
- Alternative Control Technology (ACT)

Advanced Helmet Display Systems
- Night Vision Operations Laboratory
- Visually Coupled Systems Development and Visual Interface Laboratory
- Visual Image Evaluation of Windscreens Laboratory
- Dynamic Visual Assessment Facility (DVAF)
- Color Display Laboratory (CDL)
- Aerospace Vision Laboratory (AVL)

TABLE 1-1: LIST OF HUMAN ENGINEERING DIVISION FACILITIES

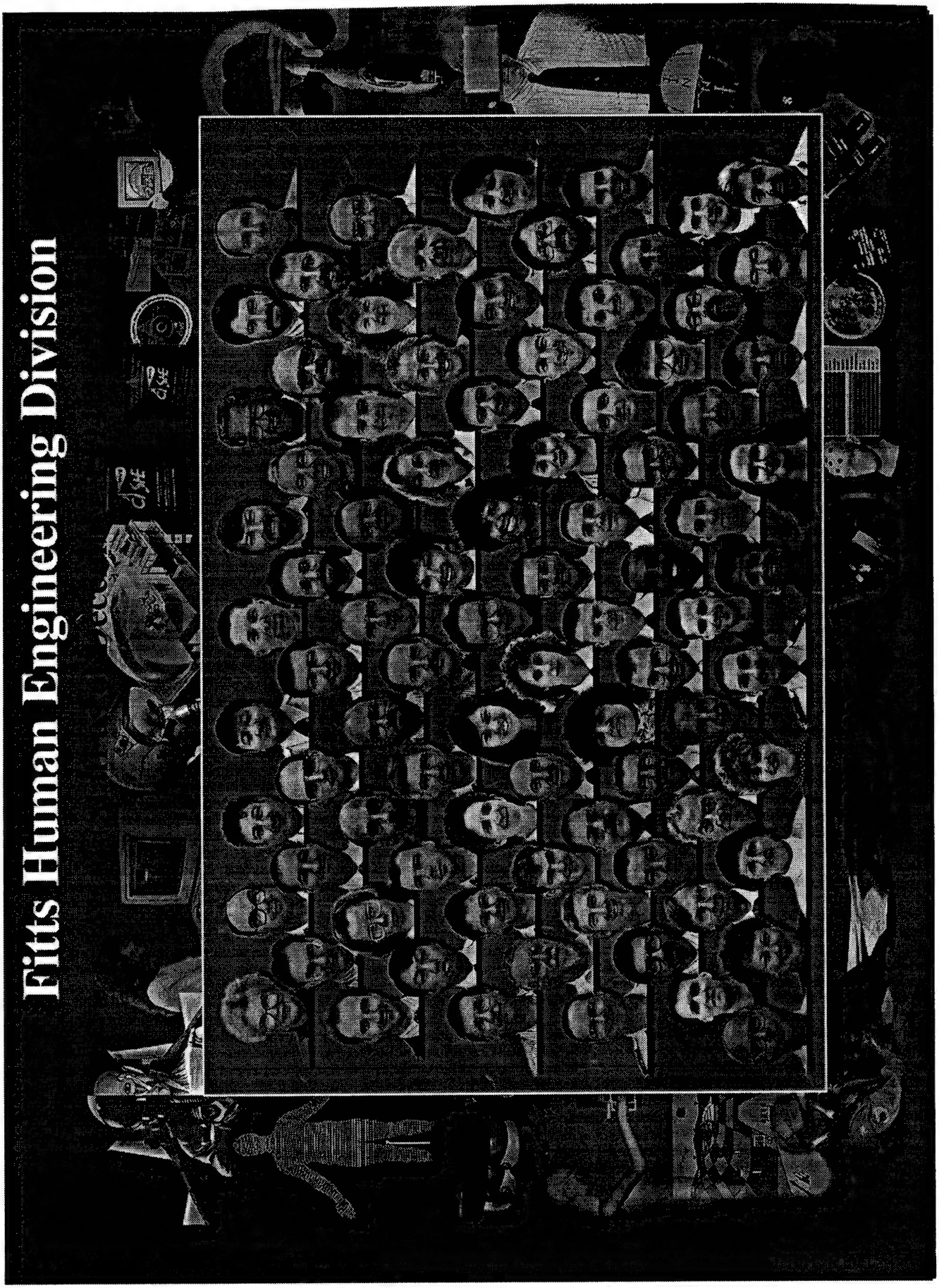
The core program, accounting for approximately 70 percent of the activity of the Fitts Human Engineering Division, is focused on building the technology base, tools, techniques, and media to leverage and extend the capabilities of future warfighters in the operation and support of complex systems. Analogous to "fire-prevention," these efforts are concerned with preventing today's problems from recurring in tomorrow's systems by anticipating USAF needs and getting "ahead of requirements." In performing this activity, user needs must often be "pushed" to recognition of emerging human engineering technologies and best practices (Figure 1-3). Our considerable success in this area is demonstrated by a sustained high percentage of customer funding of our science and technology program.

Work is executed through five Branches: Ergonomics Analysis; Design Technology; Human Interface Technology; Crew Systems Integration; and Visual Display Systems. Within the division, there are 18 specialized laboratories and facilities (Table 1-1) distributed over six buildings (Bldgs 248, 248A 33, 196, 197, 29) on Area B of Wright-Patterson AFB. The core strength of the organization is reflected in the quality and breadth of division personnel (Figure 1-4). Our present staff includes 86 civil service, military, and visiting scientists, over 60 percent of whom hold advanced degrees (26 percent MS, 35 percent PhD, two percent

FIGURE 1-4: HUMAN ENGINEERING DIVISION STAFF (AS OF DEC 94)

Top to Bottom and Left to Right (10 Rows)

1. **Anne Cato, Albert Chapin, Alan Pinkus, Capt Scott Smith, 1st Lt Bryan Christensen, Alan Straub, William Kama, Robert Osgood, Bradley Purvis**
2. **Dean Kocian, Christopher Russell, Craig Arndt, Donald Monk, David Post, Herschel Self, Gregory Zehner, John Bridenbaugh**
3. **Jeffrey Craig, Gloria Calhoun, Gilbert Kuperman, Grant McMillan, Gary Reid, Glenn Wilson, Capt Jeffrey Hoffmeister, Denise Wilson, Brian Tsou**
4. **Capt John Crist, Capt Stuart Turner, Lt Col James LaSalvia, Joe McDaniel, June Skelly, Jennifer Whitestone, Kathleen Robinette, Reuben Hann**
5. **Lee Task, Capt Larry Wiley, Maj Julie Cohen, Beverly Gable, Mark Cannon, Marya Beverly, 1st Lt Mike Kasic, Capt Luis Rodriguez, Laura Mulford**
6. **Earl Sharp, 1st Lt Michael Stratton, Lt Col Michael Eller, 1st Lt Lawrie Hamacher, Michael Haas, Mary-Louise Smith, Sqn Ldr Greg Underhill, Michael Vidulich**
7. **Lt Col Melvin O'Neal, Lt Col Paul Morton, Randall Brown, Renee Kaffenbarger, 1st Lt Ralph Korthauer, TSgt Raymond Morandi, Maj Edward Fix, Capt Michael Pietryga, Peter Marasco**
8. **Robert Eggleston, Lt Col Gerald Gleason, Nilss Aume, Nick Longinow, SSgt Otis Newsome, Philip Kulwicki, Michael McNeese, Maj Mark Waltensperger**
9. **2d Lt Darryn Bryant, Maris Vikmanis, Melvin Warrick, Walter Summers, 1st Lt Robert MacMillan, Capt Ronald Merryman, MSgt Robert Stewart, Richard Warren, Capt Steve Beyer**
10. **Robert Centers, Rebecca Green, Theresa Schiavone, Elizabeth Combs, Lt Col William Wittman, Helen Redwine-Smith, Tanya Ellifritt, Ronald Yates, TSgt Wiley Wells, Kenneth Boff**


Fitts Human Engineering Division

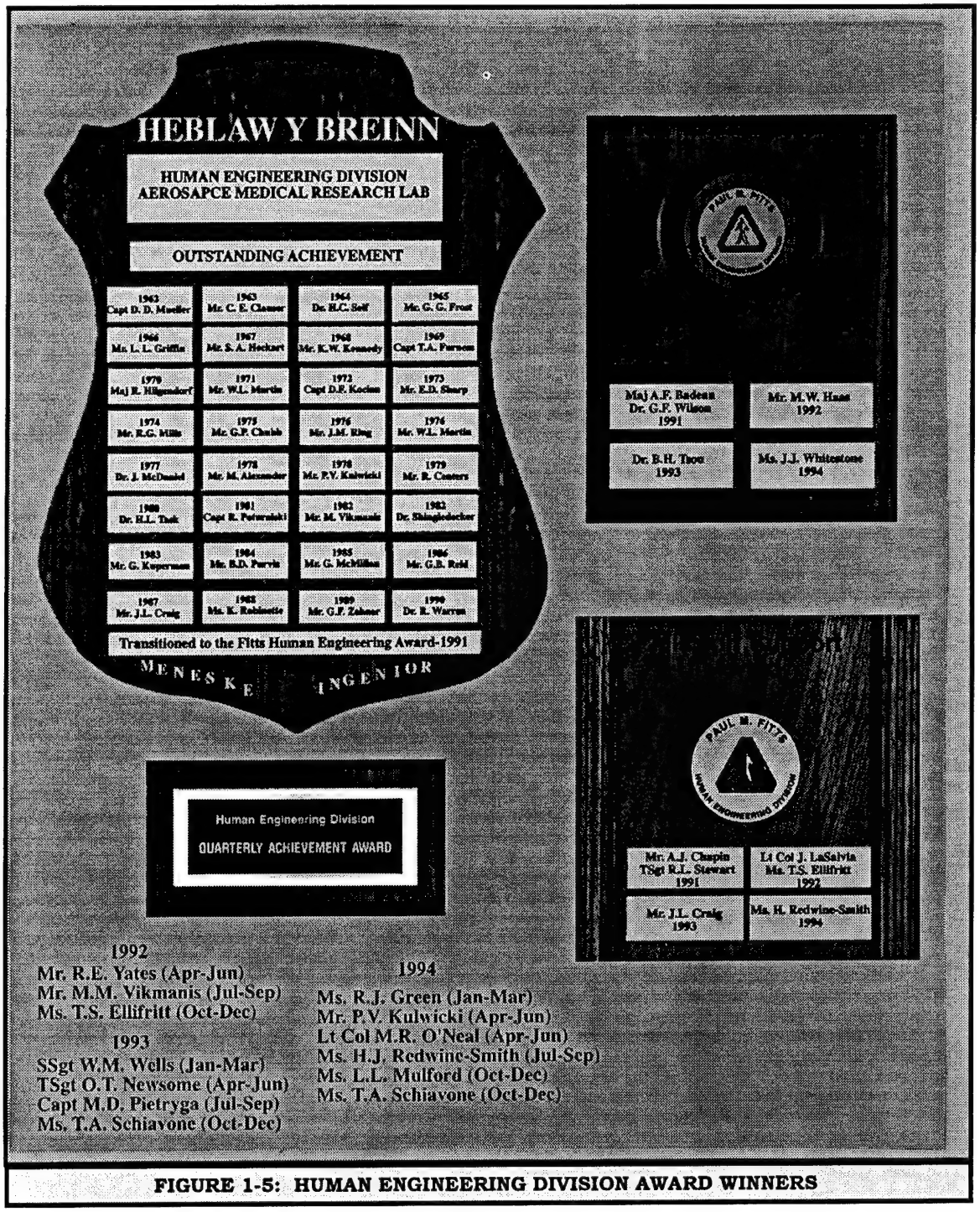


FIGURE 1-5: HUMAN ENGINEERING DIVISION AWARD WINNERS

MD) representing a wide range of scientific and engineering disciplines including psychologists, physiologists, physicists, physicians, mathematicians, computer scientists, and aeronautical, electrical, human factors, industrial, and mechanical engineers. These division researchers are generally recognized nationally and internationally in their respective areas of expertise and have collectively authored numerous scientific publications as journal articles, technical reports, books, and symposia proceedings.

Several awards are conferred to honor the achievements of division personnel. The winners of these awards are noted in Figure 1-5. The Paul M. Fitts Award for Human Engineering Excellence is awarded for significant achievement in human factors basic

science, engineering, or technology transition. It has been awarded annually since 1991, at which time it replaced the division's Human Engineer of the Year Award, first awarded in 1962. The Mission Support Award was also initiated in 1991, and is awarded annually to members of the staff who, in the spirit of total quality management, exceeded their job requirements; displayed initiative, perseverance, and dedication of mission; improved management procedures or methods of service; proved successful in administration, contract management, or coordination of programs; or successfully represented the division with outside organizations. Additionally, a division Quarterly Achievement Award is given to individuals whose accomplishments over the preceding three months have significantly furthered the Human Engineering Division or brought recognition to the division in the science and engineering communities.

Supplementing this government staff is a multi-disciplinary cadre of approximately 170 on-site support professionals representing six independent R&D companies. These are Ball Systems Engineering Division, Logicon Technical Services Inc. (LTSI), Science Applications International Corporation (SAIC), Sytronics, Inc., University of Dayton Research Institute (UDRI), and VEDA Inc. Whereas the division takes pride in its core competency and technology leadership, as demonstrated by the quality of its in-house research programs, these and other contracts with universities and industry extend our capabilities and encourage external participation.

The unique R&D assets within the Fitts Human Engineering Division make it a national center of excellence which leads the nation's human factors research efforts. Our value continues to grow with public recognition that effective human integration with complex technologies in tasks, jobs, and processes from the factory floor to the family living room is the key to affordability and international economic competitiveness. Products from our R&D investments have been extensively and successfully used by industry, academia, local government, and other federal agencies. Multi-use applications have been achieved, or are planned, in medical instrumentation and techniques, automotive interior packaging and assembly, industrial safety and job design, job performance aiding, computer-aided human engineering, and entertainment.

SECTION 1 - 50 YEARS OF HUMAN ENGINEERING: NARRATIVE HISTORY

II. HISTORY

The remainder of this section is divided into two parts: Human Engineering: 1945-1984, and Fitts Human Engineering Division: 1985-Present. This somewhat unusual structure was selected, in part, to reuse a remarkable history of the division's first 40 years, written by Dr. Walt Grether for the occasion of the 50th anniversary of the Air Force Aerospace Medical Research Laboratory. In it, he captures the flow of important events, the goals, and the mood of the organization throughout the 40-year period. Following Dr. Grether's account is a contemporary perspective of the Human Engineering Division focusing on the most recent ten years of its existence. This thorough overview of the division's structure, mission, practices, research programs, accomplishments, and facilities provides a snapshot of the division and its members today and is a sound basis for predicting the future of the organization over the next 50 years.

HUMAN ENGINEERING: THE FIRST 40 YEARS* 1945-1984

by Walter F. Grether, PhD
Chief, Psychology Branch (1949-1956)

Today we are celebrating the 50th anniversary of the founding of the great institution that is now called the Air Force Aerospace Medical Research Laboratory. During the 50 years of its existence, this laboratory has contributed immensely to the development of Military and Civil aviation, and manned space flight, in terms of the safety and effectiveness of human beings. In this paper I will discuss early activities relating to another anniversary, the 40th anniversary of what is now called the Human Engineering Division of the Aerospace Medical Research Laboratory. On 29 May 1945, HQ Army Air Forces directed the Air Material Command at Wright Field to establish a psychological research facility to study equipment design problems. As a result, there was established, on 1 July 1945, a Psychology Branch of the Aero Medical Laboratory. For convenience, in this paper I will refer to the laboratory by its common abbreviation, AMRL.

My first knowledge about the plans for this new Psychology Branch came just about this time 40 years ago. I was serving as Chief of a Psychological Examining Unit at Keesler Field, Biloxi, MS. This Psychological Examining Unit was part of a large World War II Aviation Psychology Program, under the Office of the Air Surgeon, devoted primarily to the selection and classification of Aircrew Personnel. This news came to me from Dr. Paul M. Fitts (Lt Col), stationed in the Office of the Air Surgeon. He had been selected to head the new venture at Wright Field and invited me to join. The proposed program, pioneering a new field, interested me very much, and I promptly volunteered for assignment to the new Psychology Branch of AMRL.

Most of the initial staffing of the Psychology Branch was by officers and enlisted men from the wartime Aviation Psychology Program, which, during most of the war, was centered in the AAF Training Command. At this time, 40 years ago, the war in Europe had ended, and the war in the Pacific was in its final stages. Thus, the program we were in would obviously be scaled down.

I was one of the first of the staff of the new branch to arrive at AMRL in August 1945. Dr. Fitts arrived a few days later. Soon many others, mostly military, and a few civilian, joined the new branch. We were graciously welcomed by the Laboratory Commander, Dr. William R. Lovelace, III (Colonel). Others in the laboratory also seemed pleased to see us, and made us feel very welcome. At that time most of AMRL was housed in building 29, and four adjoining one-story buildings which are still in place. An animal facility and some hydroponic gardens north of building 29 were removed long ago. Initially space was made available for us in building 29. Rather soon, as a new building was completed for the Engineering and Development Branch, we were able to expand into buildings 196 and 197. Within a few years, we learned of another new building, number 248, to be built for the Physiology Branch, thanks to Dr. Pharo Gagge, who was chief of Operations at that

* Originally written as "The Genesis of Human Engineering" for the occasion of the 50th anniversary of the Air Force Aerospace Medical Research Laboratory. Portions were published in "50 Years of Research on Man in Flight," 1985, Charles A. Dempsey.

time. Two additional floors were added to the plans for building 248, specifically for the Psychology Branch. Building 248 is still the home of the present Human Engineering Division.

With the war drawing to a close, why did the Air Force find it necessary to set up a new and pioneering program of psychological research? For the answer to this question, we have to look at some of the lessons learned from wartime combat operations. One of these lessons, as Dr. Stevens of Harvard University stated, was that "Machines Cannot Fight Alone." A major weakness in many weapon and support systems was the human operator. Far too many aircraft and their crews were lost because of pilot or navigator error. Bombing accuracy fell far short of what the systems should have been capable of delivering. Fire control by fighter aircraft, and flexible gunners, also was disappointing. Although the human operator proved to be a major weakness, it was realized that much of the fault was in the original design of the equipment, which was often poorly matched to the physical and intellectual capabilities of the men and women who had to use it. To overcome this problem much effort had gone into selecting and training the operators, but this was not enough. Research was needed to find designs which were more compatible with human capabilities.

During the war a few of these design problems had been investigated by psychologists. At the Harvard Psychoacoustic Laboratory, for example, research led to significant improvements in the design of radio communication systems. At a number of other places, psychological research efforts were applied to fire control and radar systems. In Great Britain, also, there were some wartime research efforts by psychologists on equipment design problems. The major effort was at Cambridge University, under Sir Frederick Bartlett.

It was not until after the war, however, that a major attack was made on the problems of designing equipment for human operation. At about the same time that the Air Force set up the Psychology Branch, the U.S. Navy set up several new research units with similar missions. These were at the Special Devices Center on Long Island, the Navy Electronics Laboratory at San Diego, and the Naval Research Laboratory at Anacostia, MD. In addition, the Navy initiated a major contract program with Johns Hopkins University to study Combat Information Centers. At this time, also, the Psychological Corporation in New York set up a new group to do contract work on equipment design problems. This group soon split off to become Dunlap and Associates. It was not until about 6 years later that the US Army established a Human Engineering Laboratory at Aberdeen Proving Grounds in Maryland.

At AMRL we first used the label "Engineering Psychology" for our type of activity. Our counterparts in other laboratories, however, began using other labels such as "Human Engineering," "Human Factors," "Human Factors Engineering," and "Biomechanics." Our counterparts in Great Britain used the term "Ergonomics." While all these labels are still in use, in this paper I will use the term "Human Engineering."

For those of us in the new Psychology Branch, coming to AMRL and Wright Field was a very stimulating experience. In the Training Command we were accustomed to marching cadets and training aircraft. We were also quite familiar with the then-current operational aircraft. At AMRL and Wright Field we began learning about the Air Force of the future. At AMRL we learned about partial pressure suits, advanced G suits, atomic flash protectors, and liquid oxygen converters. Being located at Wright Field, we also learned about jet aircraft, rocket engines, transistors, new concepts of air traffic control, new ideas for aircraft cockpits, and many other new areas of aviation development.

We also had much to learn about how to do things the Wright Field way. Here we suddenly became engineers, project engineers, that is. The fact that we were psychologists, and not engineers, did not seem to matter. Research work was organized into projects and tasks. Once a project was established, it went on forever, it seemed. We had to keep data in

Project Record Books, which were periodically inspected to be sure that we did it right. We also learned that most scientists in the laboratory, I mean project engineers, did not really do research. They developed and tested end items, such as new oxygen masks, G suits, partial pressure suits, and sunglasses. The Project Record system at Wright Field was geared to the development of end items, not to research. We had come to do research, and the end items to which our research would have application were the responsibility of other Wright Field laboratories, not AMRL.

Also strange to us was the reporting system we were required to use for publication of our research results. The required type of report was called a Memorandum Report, and was geared strictly to the development and evaluation of end items. It was quite inappropriate in format for the reporting of scientific experiments. Fortunately this situation was only temporary. In a few years a new type of reporting system was introduced, with the use of Technical Reports for major studies, and Technical Notes for studies of lesser scope. These reports were far more suitable for reporting scientific experiments.

Another thing we soon discovered after our arrival at AMRL was money, in this case contract money for the purchase of research equipment and research. In the process of getting our program underway we had to set up new projects and thereby get into the budget cycle for funding in future years. It turned out that other projects in the laboratory had funds surplus to their needs, and we were literally deluged with funds that were transferred to us. Thus, we soon found ourselves hustling to write work statements for research equipment that we needed, and for research that we could farm out to university contractors. We were most fortunate to have this windfall of contract money to help us launch our new program. Amazingly, we were even provided with transfer of funds from other Wright Field laboratories that were anxious to have us supervise research related to their areas of responsibility.

As I mentioned earlier, the initial staffing of the Psychology Branch was mostly officers and airmen from the wartime Aviation Psychology Program. As the war ended, most of these people separated from the Air Force and returned to universities or other civilian occupations. Some of us, including Julien Christensen and Melvin Warrick, converted to Civil Service status and stayed at AMRL. Those who left were soon replaced with other officers and enlisted men, and some civilians. Among the new additions were pilots, navigators, and bombardiers, some of them with no training in psychology. They were, however, most valuable additions to our group because of their personal knowledge of flight operations and flight crew duties. I have a picture of the Psychology Branch staff, taken in 1948 (Figure 1-6). Dr. Fitts, our most inspiring and capable leader, is seated in the center front row. We were all very sad when he left us in 1949 for a position at Ohio State University, although he continued to assist us in many ways after that. We were saddened even more when he passed away suddenly at Ann Arbor, Michigan in 1965.

At the time this picture was taken, a few members were absent and failed to get into the picture. About 10 years after this picture was taken, the Anthropology Section, under Ed Hertzberg, joined our branch. Some years later, also, our mission was expanded, and new personnel added, to include research on training, with special emphasis on design of training devices and equipment. Dr. Gordon Eckstrand headed up this new activity.

Early in our existence, to give proper direction to our research, we began visiting the nearby laboratories whose end items would be the focus of our research. These laboratories were primarily Communication and Navigation (radios, instrument landing systems, and air traffic control), Equipment (aircraft instruments, instrument and cockpit lighting), Aircraft (crew station design and layout), and Armament (radar and fire control systems). After the project engineers in these laboratories understood that we were not there to develop end items in their areas of responsibility (I think this is called turf these days), they were happy to tell us about operator problems they had encountered.

FIGURE 1-6: THE PERSONNEL OF THE AMRL PSYCHOLOGY BRANCH IN 1948
From the left, back row: Lt Wise, Mr. Bakalus, Mr. Gardener, Miss Fuerst, Mr. Roettele, Miss Connell, Mr. Warrick, Mrs. Morris, Mr. Christensen, MSgt Kake, Sgt Edison, and Mr. White Seated in the front row, from left: Capt Jones, Maj Long, Dr. Fitts, Dr. Grether, Dr. Biel, and Capt Wilcox.

They were very receptive to the idea of having us conduct human engineering research applicable to their equipment. From our discussions of these problems with them, we gained many valuable research ideas. For some of the problems they described, we could provide data from the available psychological research literature. They brought up other problems, however, which we saw no way of solving through research we could visualize. We also received some wild proposals, and these we politely rejected. One such proposal came to us in a letter requesting us to supervise a research program on Extra Sensory Perception, as a possible substitute for radio communication. I was quite familiar with research literature in this field, and sent them a diplomatic reply explaining why such research would not be productive.

In this paper, I will briefly describe some of our very early research efforts, and the successes or failures of these in terms of applications to Air Force equipment. Some of these studies were originally reported in Volume 19, of the AAF Aviation Psychology Program Research Reports (4) which the branch had ready for publication in October 1946.

For his effort to educate himself about problems needing research attention,

particular credit must go to Julien Christensen, a former AF navigator. Dr. Christensen (2) arranged to conduct activity analyses of navigators in B-29 aircraft during very long operational-type missions, mostly in the Arctic. This gave him valuable data on how the navigators carried out their duties in our newest operational bomber, how their work time was distributed, and what problems they faced. It also gave Chris membership in the Pole Vaulter's Club, and the right to the claim as the first civilian to fly over the North Pole in an Air Force aircraft. Christensen also conducted research on errors made by navigators in using their standard navigation plotter. His experimental evaluation (3) of several different plotter designs led him to design an improved plotter which became the standard for use in the Air Force. This was the first, and one of the few end items ever developed by the Psychology Branch.

A major problem that had plagued the Air Force during the war, and before, was pilot error as a major cause of aircraft accidents. Statistical data maintained by the Directorate of Flight Safety Research, at Norton AFB, San Bernardino CA, consistently showed that about 75% of major aircraft accidents were attributable to pilot error. It can be argued that many of these were really designers' errors, that trapped the pilots into making what were often fatal mistakes. A very common type of error was activation of the wrong control. At that time each type of aircraft had a different arrangement of controls and instruments in the cockpit. Thus, when a pilot changed from one type of aircraft to another he was very like to reach for the wrong control, or read the wrong instrument. Also, some controls were located in places where they were difficult to reach or to see. This particular source of pilot error was largely eliminated in future aircraft by two major changes in cockpit design: (1) standardized location of major controls and instruments in the cockpit, and (2) shape coding of major cockpit controls. Thus, when a pilot transferred to a different type of aircraft he did not have to relearn the location of major cockpit items, and major controls could be identified by touch alone. These changes were implemented primarily by the Crew Stations Branch of the Aircraft Laboratory, with much technical input from members of the Psychology Branch, using the results of several experiments. One of these experiments, by William Jenkins (10), tested the identifiability by touch alone, among a group of shape-coded control knobs. Figure 1-7 shows the knobs that were included in this experiment. Pilot Dick Jones is shown as the subject. Another experiment, by Fitts and Crannell (5), measured the accuracy with which pilots could reach to possible control locations in the cockpit. An experiment by Mel Warrick (13) determined the preferred relationships between control movements and instrument indications when these were located in different axes or planes in the cockpit. The Anthropology Section (which later transferred to the Psychology Branch) provided very essential data about cockpit sizing to accommodate the full range of pilots' body dimensions.

An important aspect of the cockpit standardization effort was agreement on a standardized arrangement of the six flight instruments, namely the horizon, altitude, air speed, rate of climb, heading, and rate of turn instruments. A major contribution toward agreement on the best arrangement of these instruments came from a pilot eye movement study conducted by Fitts, Jones and Milton (7) in a C-45 aircraft assigned to the branch. This study measured the frequency and pattern of eye movements during different phases of flight.

As already mentioned, pilot error had been a major cause of aircraft accidents. In most cases the pilots could not be interrogated to determine the exact nature of the error, and this could only be deduced from the accident data. One of the first studies conducted in our branch was an interview study by Fitts and Jones (6) in which pilots were asked to recall and describe errors they had made in flight that could have resulted in accidents. Among these were errors in reading instruments. A sample of some of the findings regarding

FIGURE 1-7: CODING AIRCRAFT CONTROL KNOBS
Knobs employed in a study of shapes for use in coding aircraft control knobs. (Capt Richard E. Jones as subject). From Jenkins (10).

instrument reading errors is shown in Table 1-2. You will note that the category with the highest frequency of errors was in reading multirevolution instruments. Mostly these were errors in reading the standard three-pointer altimeter used in most military and civilian aircraft at the time. This finding led me to conduct an experimental study of altimeter reading (8), using nine different types of altitude display that might be suitable for use in aircraft. Both college students and pilots were used as subjects. The results show that this instrument takes a rather long time for reading, and yields a high percentage of reading errors. Unfortunately, many of the reading errors were in the hazardous direction of reading the altitude as higher than it actually was. The most common mistake was to read the altitude as exactly 1,000 feet too high. We believe this type of reading error accounts for a great many unexplained accidents in the past, where aircraft hit mountains just below the peak, or landed just short of the runway on instrument approaches to landing.

Based upon the results of this experiment, I recommended that the altimeter be redesigned to provide a display which uses a single pointer making one revolution for each 1,000 feet change of altitude. An added odometer type of indicator displays thousands and ten-thousands of feet altitude. Both pilots and college students made almost no errors with this display, and reading time was very short. In ensuing years several investigators in other laboratories conducted experiments with similar displays and corroborated these results. Unfortunately, the engineers responsible for altimeter design were unwilling to give up the mechanically reliable three-pointer design. It was not until about 20 years later that the altimeter was changed to provide the greatly improved type of display. The change was then made because a redesigned instrument was needed so that altitude could be automatically transmitted by radio link to the ground, for air traffic control purposes. The improved type of altitude display is now standard in most military and commercial aircraft.

These are a few of what you might call successful outcomes of our early research. Some of our other studies might be of equal interest, even though they did not produce the hoped-for results. As we know, negative results, or results that do not lead to practical applications, can also be of great value.

Late in the war the B-29 was a very important aircraft in our inventory, and it played a key role in ending the war in the Pacific. In this aircraft, at the waist gunner station, was a very advanced type of gun sight known as the pedestal sight. Gunners had considerable difficulty in using this sight, and accuracy was considerably below expectations. We were requested by the Armament

TABLE 1-2

Classification of 270 Errors Made by Aircraft Pilots in Reading Instruments
(Modified from Fitts and Jones, 1947)

Type Error	Percent
Misinterpreting Multi-Revolution Instruments	18%
Misinterpreting Direction of Indicator Movement (Reversal Errors)	17%
Misinterpreting Visual and Auditory Signals	14%
Errors Involving Poor Legibility	14%
Failing to Identify a Display	13%
Using an Inoperative Instrument	9%
Misinterpreting Scale Values	6%
Errors Associated with Illusions	5%
Omitting the Reading of an Instrument	4%

Laboratory to evaluate two sets of redesigned controls for this sight. The original controls, because of their design, caused interference for the operator between the separate tasks of controlling elevation, azimuth, range, and triggering. Also, an undue part of the load was given to the left hand. It was rumored that the designer of the sight was left-handed. An experiment, conducted by Johnson and Milton (11), showed one of the redesigned sets of controls to be clearly superior to the original controls. In this instance, however, no effort was made to install the improved controls in B-29 aircraft, since further combat use of this aircraft seemed unlikely.

As mentioned earlier, our branch had a C-45 aircraft assigned to it, and this was used very successfully for experimentally recording eye movements in flight. This success led us to request a larger aircraft, a C-47, for research on other aspects of pilot performance, with special emphasis on pilot fatigue. A question that we encountered quite often was "How long can a pilot fly safe under instrument conditions?" Past research on fatigue, by others, had generally been disappointing. Although pilot fatigue seems to be a genuine problem, and a serious flight hazard, this condition had been extremely resistant to objective measurement. We had the C-47 aircraft equipped with a remote panel of instruments, for photographic recording of pilot performance. Missions were flown with the pilot under an instrument flying hood. The missions were 14 hours in length, with a refueling stop at midpoint. Detailed analysis of the instrument recordings failed to show a significant decrement during the 14 hour missions. There were, however, subjective indications that the pilots were quite fatigued. One of the pilots, in his hurry to get home and rest, hit another car as he backed out of his parking space.

Another research area to which we gave considerable attention, and some research, was the issue of "Fly To" and "Fly From" on aircraft instruments. Another way of stating the question was, should the moving element of the instrument represent the aircraft (a "Fly From" indication), or should it represent the earth (a "Fly to" indication)? On most instruments the moving element represents the earth. This conflict could be expected to cause habit interference on the part of pilots. Our pilot interview studies referred to earlier showed that pilots frequently made reversal errors in flying the gyro horizon and radio compass. A wartime study by Loucks (12) at the AF School of Aviation Medicine had shown that it was more natural to fly the moving bar

of the gyro horizon as if it were the aircraft, rather than the horizon. Similar results were obtained by Brown (1) in Great Britain. Early in our program we acquired a wartime Link Trainer, and two of our employees, Joe Bakalus and Bob Roetelle, were former Link Trainer operators. With their help, John Gardner, one of our pilots, did a study of methods of horizon display. His results agreed with those of previous studies. A change to the moving aircraft type of display was, however, never seriously considered by the engineers responsible for the design of flight instruments. In retrospect, I think they were probably right. For a rather long time now the standard gyro horizon display has been a stabilized sphere, which can display all possible aircraft attitudes. The moving aircraft type of display, as far as I know, is not amenable to such all-attitude representation.

There was another long-standing idea that engaged some of our early thinking. Actually this was not so much our idea, as that of anthropologists and biophysicists in AMRL. This was the idea that the pilot, in a fighter aircraft, might fly in the prone position, as the Wright brothers did in their first aircraft. This position would give the pilot considerably increased G tolerance, and would also permit a reduced vertical cross section of the aircraft. The Psychology Branch provided some help in testing this idea. Through a contract with the University of California at Berkeley, we had a set of controls constructed for flying in the prone position. Under the auspices of the Anthropology Section a prone position bed, and the controls, were installed in the nose of a B-17 aircraft as a test vehicle. Quite a few of us had a chance to actually fly the B-17 using this novel arrangement. I think even the anthropologists agreed that this position had some serious disadvantages, among them being the difficulty of forward and upward vision. The idea seems to have been laid to rest as a result of this trial.

In this report I have given you a flashback to some of the pioneering research of the Psychology Branch during the first five years of its existence, and I showed how some of these research studies contributed to aviation development. In the ensuing years, the Psychology Branch, later renamed the Human Engineering Division, continued as a leading organization for Human Engineering research. Beginning in the late 1950s, as manned space flight became a possibility, much research of the branch was directed to problems of working under zero-gravity conditions, cycling of work and rest during prolonged confinement, and other problems related to manned flight in space. During some of the same period, as our nation was engaged in the Vietnam War, other research efforts were directed to Limited War types of aviation operations. Major contributions were made in both of these rather different areas. From the modest beginning made by the Psychology Branch, and several parallel research organizations in the US Navy about 40 years ago, Human Engineering has grown into a large and widespread area of applied science. There are now probably several thousand persons employed as Human Engineers in this country, in the Department of Defense, in defense and nondefense industries, consulting firms, and universities. Some of this expansion of Human Engineering was covered in a review I prepared in 1966 (9).

In conclusion I would like to express my personal satisfaction with the 28 years I spent at AMRL. Approximately seven of those years were as Chief of the Psychology Branch, following Dr. Fitts. The remaining years were in various staff positions. I enjoyed my association with the medical and medically related specialists who made up the laboratory. I also enjoyed my close association with development engineers in other Wright Field laboratories.

After 40 years the Human Engineering Division is still a vigorous and productive organization. This is due in large part to the leadership provided by Dr. Julien Christensen, who followed me as Chief, and Charles Bates, the present Chief. It is also testimony to the past history of accomplishments of this organization, and to the administrative support and scientific environment provided by AMRL.

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FITTS HUMAN ENGINEERING DIVISION: 1985-PRESENT

A. INTRODUCTION

During the last ten years, the Human Engineering Division of the Armstrong Laboratory has been very productive in many areas. In appraising just how productive the division has been during these years, it is important to keep in mind that the division is a research and development (R&D) organization with two products or outputs: its publications and its direct assistance to organizations that develop, evaluate, and use man-machine systems. The division conducts both laboratory and field studies to collect data on the physical and mental abilities of people for use in designing, developing, and applying man-machine systems. These data allow tailoring of equipment to fit its users so that man-machine systems fully utilize the abilities of both the equipment and its users.

A cursory examination of the entries in the bibliography over the last ten-year period reveals that, during this period, the Human Engineering Division was a prolific publisher of journal articles and technical reports. However, it should be noted that the bibliography does not fully reveal the extent of direct assistance and development work by the division, since an appreciable part of the development work had security classifications that prevent inclusion in this volume. The authors of this document readily admit that not all research and development conducted in the Human Engineering Division is represented in this work. Because of classification, sensitivity, expediency, or oversight, the work of many talented researchers was unfairly underrepresented or omitted altogether. In those cases, we beg your indulgence. We felt that complete representation was not practical and, in fact, not desirable. Our goal was the inclusion of a broad, representative set of topics illustrating the major activities of the organization and the time. Again, our apologies to those whose work has been slighted.

During the last ten years, much of the research and development work of the Human Engineering Division on specific topics and problems was continued from previous years, because many of the problems required still better solutions. In some cases, changes made in systems under investigation required new human engineering inputs for evaluation. In some cases, new problems surfaced during use of new systems. In the relatively short span of the last ten years, the advance of technology has caused significant changes in both the equipment used by the armed forces and in laboratory equipment. The constant pressure to increase operational effectiveness and maintainability while decreasing lifetime cost of ownership of aircraft and space vehicles was accompanied by changes in their displays, controls, operating procedures, and combat tactics. Changes were usually in the direction of increased complexity and were not always effective.

Increased use of computers is one factor influencing division work. Although digital computers have been around for several years, in the last ten years there has been an appreciable increase in the number of computers and output media in offices, laboratories, and military systems. There has also been a large increase in the percentage of laboratory and operational equipment having digital indicators and displays, with digital devices in many cases replacing analog devices. Instruments for measuring many quantities, such as the amount of fuel in a tank, aircraft speed, weight, dimensions of parts of the human body, strength, etc., are now automatically converted at the measuring device to digital form for display and for storage in computer memory. Increasingly, the process of collecting data bypasses the need to read numerical values and manually record them by writing or keyboard use. Once

in the computer, statistical data analysis programs allow computers to perform any desired statistical calculations, provide tables of numerical values, and draw graphs, charts, and complex illustrations. The technical reports on the results of research and development efforts are now written with the aid of word processors, frequently by the engineers and scientists using their own computers.

To illustrate the effect of the digital revolution on the work of the Human Engineering Division, in 1988 the division's physical anthropologists acquired a computer-controlled laser scanner that automatically measured the three-dimensional (3-D) coordinates of human heads and recorded the data in computer memory. The computer data have been used to automatically control a milling machine that turns a block of material into a replica of the scanned head. Within a brief time after a subject is scanned, a 3-D solid replica of the head is available. Formerly, several days to weeks were required. The scanner greatly increases the ability of the division to collect survey data for designing or evaluating helmets and head-carried equipment, such as oxygen masks and night vision goggles.

There is still plenty of work to be done; as technology advances, new problems will occur and old ones will require better solutions. Hence, human engineering must also advance. The Human Engineering Division has an important role in this advancement, and is looking forward to the next 50 years of human engineering.

B. SCIENCE & TECHNOLOGY PROGRAMS

1. Human-System Performance Research

Performance and Workload Assessment
This research and development activity was directed toward generating subjective, behavioral, and physiological metrics and measurement methods for evaluating operator workload, situation awareness, and decision making in Air Force systems. This research has had two principal foci: workload and situation awareness measurement. These two areas can be thought of as representing attempts to quantify the demands placed on a system operator compared to his/her ability to accommodate the demand in performing the mission (workload) and quantifying or characterizing the quality of the information processing while the operator is performing his/her mission (situation awareness). The tools developed during this period have played an important role in comparing alternative interface designs and establishing the viability of a specific design for achieving mission requirements.

In June of 1979, the Workload and Ergonomics Branch was formed to address a growing concern of Air Force operators and planners about the information processing demands being placed on systems operators of emerging high-technology systems. The Branch Chief, Maj Robert O'Donnell, assembled a team of government scientists, contractors, and academic researchers to pursue a three-pronged research program to develop metrics of human mental workload. The act of organizing a branch around a technical problem, in and of itself, was unique. Typically, human factors organizations are organized around generic, operationally oriented factors such as controls, displays, or training.

Mental workload became a very hot research topic in universities and government laboratories around the world. Additionally, the problem of information in aircraft cockpits became so widely acknowledged that, in 1979, the Commander of Air Force Systems Command, General Alton Slay, proclaimed it as one of the Air Force's most pressing problems. He mandated that all new aircraft designs should take pilot workload into consideration.

Emerging technology increased operator workload in several ways. Expanded system capabilities, with a concomitant increase of displayed information, created unprecedented demands on operator attention and resources. Secondly, advances in automation technology led managers to believe that complex flight

tasks could be performed with smaller crews, since large components of the tasks could be turned over to machines. This combination of events dramatically changed the nature of cockpit tasks. The push to reduce crew size was also taken up in the private sector by the airlines. When the Boeing 757 was being prepared for certification, there was a push to certify the aircraft for a two-man crew. Due to the critical nature of the issues involving many components of national interest, President Reagan formed a special Presidential Advisory Commission on Aircraft Crew Complement. Lt Col Robert O'Donnell was named as a staff member for the commission and played a very active role in producing the commission's report.

Generally, research in mental workload took one of three approaches: subjective measures, behavioral or performance measures, and physiological measures. Behavioral approaches, especially secondary task methodology, helped to define the construct of mental workload as multi-dimensional and, in some way, related to the allocation of mental resources among tasks. Subjective approaches were believed to be the most widely used, especially in operational testing. Few could argue that some method of having people estimate how hard they were working was a necessary part of studying workload. Other measurement methods ultimately have to pass the test of corresponding with what the operator believes to be true. Finally, physiological measures have had a great deal of appeal as objective ways to reflect how hard the organism is working. Academic research at the time, especially by Dr. E. Donchin at University of Illinois, focused on evoked cortical response that could be shown to have a relationship to cognitive activity. The implications for measuring workload were unavoidable.

Research, especially in the areas of behavioral models and physiological phenomena, was widespread. However, the Workload and Ergonomics Branch was the only place where all three approaches were brought together into a unified program where they could be used to complement each other in the investigation of this complex construct.

Behavioral/Performance Measures: This work was heavily influenced by the research of Dr. Christopher Wickens, of the University of Illinois, who authored a multiple resources model of human information processing. Dr. Clark Shingledecker and Dr. Thomas Eggemeier, members of the newly formed branch, explored the use of secondary task methodology. Eggemeier's work included development of a conceptual framework for mental workload that was the theoretical basis for the entire branch research program. Dr. Shingledecker explored ways to use naturally occurring task components as if they were laboratory secondary tasks and, thus, developed a methodology known as Embedded Secondary Tasks. He also studied the use of other non-intrusive tasks, such as rhythmic tapping, as indices of primary task load.

Dr. Shingledecker led a team that developed the Criterion Task Set (CTS) and released it for general use in 1984. The CTS was a unique task battery based on a model of information processing. The idea behind the battery was to develop a series of tasks that would tap specific mental resources. The goal of the task battery was to provide a standard test battery to use in evaluation and validation of proposed workload measures. This task battery work then expanded, and Dr. Shingledecker was asked to participate in a Tri-Services Working Group, chaired by Dr. Fred Hegge of Walter Reed Army Medical Center, assigned to develop a task battery for use in screening chemical defense drugs. Drugs that were being developed to counteract potential weapons often have undesirable performance effects. The Unified Tri-Services Cognitive Performance Assessment Battery (UTC PAB) was developed and extensively tested here and under contract with the University of Oklahoma.

Work on the UTC PAB spawned international interest in development of a standardized performance battery and procedures. An AFOSR-sponsored meeting hosted by A. N. Sanders at the University of Aachen, Germany was held and an AGARD working group was formed to direct the battery development. Lt Col O'Donnell presided over

the Aachen meeting where Dr. G. Santucci of CERMA, Paris, France was selected as the permanent chairperson. Dr. Glenn Wilson became the Workload and Ergonomics Branch representative and the NATO/STRES (Standardized Tests for Research on Environmental Stressors) was developed. The purpose of this battery was to provide the international research community with an agreed upon, standardized group of tasks and procedures to promote exchange of information and data on human performance limitations.

Physiological Measures: The work by Drs. Donchin and Wickens on the cortical evoked response was the starting point for the development of physiological measures. From the very beginning, the objective was to package a state-of-the-art physiological test battery that could be used in research on mental workload and in Air Force tests measuring mental workload. The battery was unique in that it included the cortical evoked response, steady state evoked response, brain-stem evoked response, several heart rate measures, electromyographic measures, respiration, and eye movement. The first battery was called the Neuropsychological Workload Test Battery (NWTB) and was unique in that it had test procedures, data collection capabilities, and data analysis capabilities combined in one device. These devices were delivered to other researchers in England, the National Drug Institute, Boeing, Northrop, and the Navy.

A major spinoff of this work was the development of a clinical evoked potential laboratory in association with the Wright-Patterson AFB Medical Center, where cortical and brain-stem evoked responses were used for audiometric and vision testing in difficult cases such as premature infants and multiple sclerosis patients. These techniques have now become standard clinical practice.
Col O'Donnell also consulted with Miami Valley Hospital where a similar facility was developed.

A significant basic research program resulted in the first DOD magnetoencephalography (MEG) laboratory. The MEG work was based on the work of Dr. Lloyd Kaufman (New York University) and others, who had made significant progress in using measurement of magnetic fields to localize origins of electrical activity associated with cognitive activity. This basic research program was used to elucidate the brain activity associated with cognitive activity and to supplement EEG approaches. The facility was developed by Lt Col Charles Hatsell, M.D. and has provided a fertile research area for cooperative research with AFIT graduate students and visiting scientists from Europe.

Dr. Glenn Wilson took over the physiology laboratory when Col O'Donnell retired and has extended the laboratory work of O'Donnell into flight. In 1981, he was the first person to actually record evoked potentials in flight. The current test battery, the Psychophysiological Assessment Test System (PATS), was built upon the work of two generations of NWTBs. PATS has refined the tests and measures that are available, increased the number of data recording channels, and greatly enhanced the user interface. Another device, the Workload Assessment Monitor (WAM), was developed in 1994 as a portable data collection and measurement device. While there are many portable recorders available, the WAM is the first device with built-in, real-time measurement capabilities.

In addition to the evoked potential work, Dr. Wilson accelerated the development of peripheral measures, such as heart rate, heart rate variability, and eye movements for in-flight workload measurement. In addition to his research flights at Wright-Patterson and surrounding bases, Dr. Wilson consulted with test teams at Air Force Operational Test and Evaluation Center (AFOTEC) and AF Flight Test Center (AFFTC) and has been instrumental in having some of these techniques used in test programs with the B-1B and C-17 aircraft.

Subjective Measures: When the Workload and Ergonomics Branch was formed, it was widely accepted that subjective measures were the primary workload evaluation techniques in

use. It was soon discovered, though, that while subjective approaches were often used, they generally were designed specifically for a given test, and were often modifications of techniques designed for evaluating other phenomena, such as aircraft handling qualities. There was no systematically developed and evaluated measurement system. Using Dr. Eggemeier's Conceptual Framework for Workload, an operational definition of mental workload was developed as a multi-dimensional construct. Dr. Thomas Nygren, from The Ohio State University, helped develop a conjoint analysis mathematical approach to developing a mental workload rating scale (1981). Dr. Gary Reid led the team through an extensive program of evaluation (1982-1985) to establish the measurement qualities and procedures, and refine the Subjective Workload Assessment Technique (SWAT) (Figure 1-8). SWAT was the first thoroughly developed and validated workload measurement approach, and is still one of the most widely used workload assessment approaches. Reid has been instrumental in applying SWAT in a large number of flight and simulator environments and has consulted extensively with the Air Force Flight Test Center and the Air Force Operational Test and Evaluation Center where SWAT is the standard workload measurement technique. Additionally, SWAT has been internationally accepted. Reid consulted with both the French Air Force and the German Air Force for translations of SWAT into French and German language versions.

Another subjective measure of workload is the Subjective Workload Dominance (SWORD) technique (Figure 1-9) which capitalizes on the ability of subject matter experts to make relative judgments about differences in workload. This retrospective technique has proven highly reliable and useful for establishing causes for high workload in operational settings. SWAT and SWORD are frequently used in unison to provide a more complete evaluation of operational systems.

In 1993, Drs. Gary Reid and Mike Vidulich provided support to a Wright Laboratory Technology Demonstration Program (Quiet Knight II) flight test. The Quiet Knight

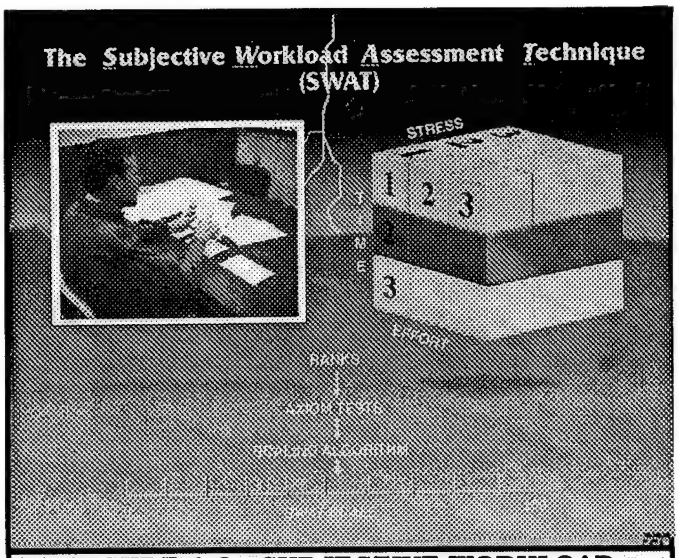


FIGURE 1-8: SUBJECTIVE WORKLOAD ASSESSMENT TECHNIQUE (SWAT)
The SWAT was the first subjective workload metric developed at the lab. It has been widely used in the AF and throughout the world. (Project 718414)

II system was designed to make dramatic changes to the way an aircrew will perform their duties for a low-level, night-penetration mission. The purpose of the crew workload evaluation in this test program was to give an early indication of the impact of the proposed system design and task distribution on crew workload. Two subjective measurement techniques were employed: SWAT and SWORD. In general, the test demonstrated that the Quiet Knight II performs the missions

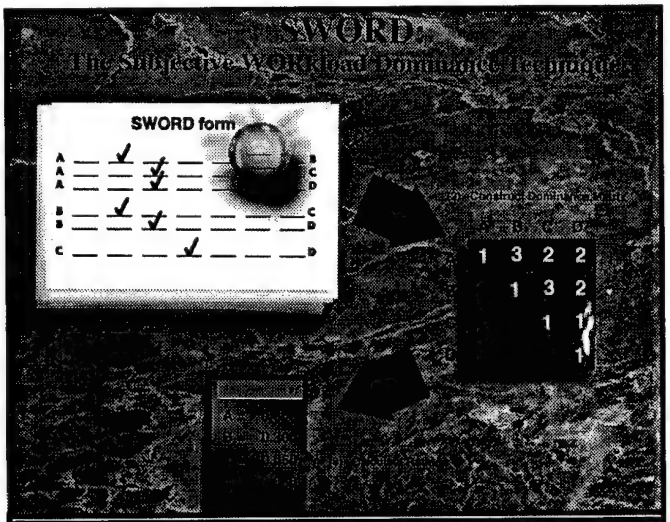


FIGURE 1-9: SUBJECTIVE WORKLOAD DOMINANCE (SWORD) TECHNIQUE
The SWORD technique is a more recent tool developed to complement SWAT in human interface evaluations. (Task 718414)

very well, and crew workload is maintained at a highly acceptable level.

Basic Visual Performance

The basic vision research program under Dr. Mark Cannon has received continuing support from the Air Force Office of Scientific Research (AFOSR) for the past 10 years. When most visual researchers were concerned primarily with measuring thresholds for detection and discrimination, this program pioneered the use of contrast scaling techniques to investigate how the appearance of targets changed with contrast. Investigations were performed for both central and peripheral vision, demonstrating that the spatial frequency pass band characteristics of the human visual system, determined from threshold experiments, did not transfer into the realm of normal everyday suprathreshold vision. These experiments were followed by development of a quantitative model of spatial pattern processing in the human visual system that could predict both the detection thresholds and suprathreshold perceived contrast of spatially localized targets presented on a uniform background. The development of this model earned Dr. Cannon a share of the US Air Force Basic Research Award in 1991. As expected, subsequent research revealed shortcomings in the model. These are being addressed by current research into the effects of background texture on the appearance of a target. Experiments have shown that background texture, similar to the target's internal structure, can produce significant changes in the perceived contrast and threshold of the target. This effect has been successfully modeled as divisive lateral inhibition and will be incorporated into the earlier visual model. The rationale behind the continuing development of this model is that its structure, consisting of parallel spatial filters and non-linear transducer functions, is something that can be easily understood by display and sensor design engineers. A fully developed model will make an ideal tool to evaluate display and sensor designs for image quality and target detection capability while it is still in the planning stage. A current reorganization of the lab will offer greater opportunities to apply the results from this basic vision research to display development programs. The research program has produced two book chapters, many articles in peer reviewed journals, many presentations at vision conferences, and several invited lectures at conferences devoted to display technology. Journal articles published under this program are highly referenced in the vision literature. The laboratory has hosted several scientists under AFOSR-sponsored programs.

Camouflage, Concealment, Deception and Obscuration (CCDO)

The Camouflage, Concealment, Deception and Obscuration (CCDO) Program, initiated by Capt Mike Tutin, Dr. Lee Task, and Mr. Bill Kama, and continued by Capt Mike Dowler and Ms. Denise Wilson, with considerable support by SRL and SAIC, developed and evaluated techniques and devices to increase aircraft and airbase survivability by reducing their detectability. The objectives were to simulate and model air-to-ground visual target acquisition of US and allied airbase assets for development, design, and evaluation of masking and camouflage patterns. Working closely with the Air Staff, AL personnel assisted in drafting an Air Force Regulation for Tactical Deception. The program led to the development and test of low-cost but highly effective aircraft decoys. The AL team also participated in a series of CONUS and OCONUS field exercises directed at quantifying the vulnerability of US and NATO airbases and the effectiveness of decoys, tonedown painting, and other vulnerability reduction techniques (Figure 1-10).

Experimental Man-in-Space (EXMIS)

In the early 1980s, the US Air Force was directed to participate with NASA in the Space Transportation System (STS) Program, otherwise known as the Space Shuttle. This meant that some shuttle launches would be designated DOD and would be partially classified to accommodate the launch of military satellites. As part of this activity, the Military Man-In-Space (MMIS) Program

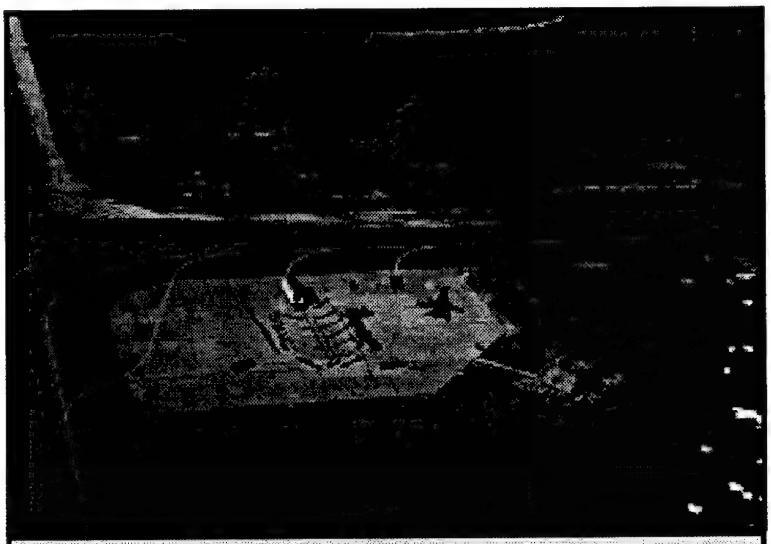


FIGURE 1-10: DEVELOPMENT AND TEST OF AIRCRAFT DECOYS

Development and evaluation of low-cost aircraft decoys and other countermeasures to visual target acquisition have contributed to the Air Force Airbase Operability Program. (Task 689301)

solicited for secondary experiments to be conducted aboard these DOD shuttle missions. Dr. Lee Task and Lt Col Lou Genco proposed a series of vision studies involving both in-cabin equipment and out-cabin viewing. The vision studies proposed were an extension of the studies conducted by S. Q. Duntley during the 1960s on the Gemini program. These studies were based on some astronauts' contentions that their vision changed (some improved, some degraded) while in orbit. This led to the development of three different types of visual function testers (VFTs) conceived by Dr. Task and Lt Col Genco. VFT-1 was designed to be a self-administered, battery-operated test of visual acuity (far vision), stereopsis, eye muscle balance (vertical, horizontal, and cyclophoria), and eye dominance. VFT-1 flew on a total of eight shuttles, with data collected on 30 astronauts over a period of seven years. Lt Col Mel O'Neal joined the group during this period and was responsible for manifesting the device and collecting the data during the later series of VFT-1 flights. These data demonstrated that there were no overall group changes to vision due to space flight conditions for the visual functions studied, but there were some interestingly significant individual changes, especially in stereopsis, for two of the astronauts studied. VFT-2 was designed to test the visual contrast threshold (contrast sensitivity) of the astronauts' vision to determine whether or not Soviet claims to "significant degradation" of contrast sensitivity during short-term space flight could be substantiated. VFT-2 flew on six shuttle flights with the data collected on 14 astronauts demonstrating that there were no significant group changes in contrast sensitivity due to space flight. The VFT-2 series was conducted by Lt Col O'Neal and Dr. Lee Task over a seven-year period ending in late 1992.

VFT-3 was intended to be a color vision testing device to explore astronauts' comments regarding apparent changes in their color vision while in orbit. However, the requirements for the device to be self-administered, sufficiently accurate to assess small changes in color vision, battery powered, and space qualified proved too difficult, resulting in the abandonment of the device in the late 1980s.

VFT-4, the final vision testing device in this series, was designed to investigate the changes in visual near and far points and speed of visual accommodation (focusing) due to microgravity. This vision test was inspired by some astronauts' stories that they had difficulty reading in orbit and had to use their reading glasses, whereas they used their reading glasses optionally while on Earth. Lt Col Gerald Gleason was the primary force in getting VFT-4 manifested for flight on STS 59 during April of 1994 for its maiden space flight. It is hoped that data will eventually be obtained on a total of ten astronauts before concluding VFT-4 flights and this series of vision tests.

In the late 1980s, the Military Man-In-Space program became interested in the previously rejected out-cabin vision experiments. This led to the development of SpaDVOS (Spaceborne Direct View Optical System) which was basically a six-to-one zoom telescope that could be mounted to the aft flight deck overhead windows for convenience in steering the telescope. In addition, SpaDVOS provided a cueing display to help

steer astronauts to specific pre-planned points of interest. Several people worked on the development of SpaDVOS, including Dr. Lee Task, Capt Harold Merkel, Capt Jim Whiteley, 1st Lt Pete LaPuma, Capt Scott Hoskins (from HSC), and a multitude of personnel from the University of Dayton Research Institute and Systems Research Laboratories. SpaDVOS was flown on two shuttle missions. During the first mission it was manually steered, and, on the second, it was upgraded to a motorized steering mode. The objective was to compare the level of visual information extraction possible through the telescope with the visual performance of the observers as measured by VFT-1. There was also interest in simply determining what level of visual information could be extracted in this manner in a real-time fashion. The results indicated the biggest problem limiting visual information extraction was the stability of the imagery due to difficulty in smooth tracking.

FIGURE 1-11: ENGINEERING RESEARCH SIMULATOR
Concept demonstrations of advanced controls and displays are evaluated in multi-operator environment. (Workunit 71841045)

B-52/B-1/B-2 Systems Integration and Design Evaluation

As mission requirements change, and with the advent of new technologies, changes to existing weapon systems and addition of new subsystems are necessary to implement new mission capabilities. In the traditional crew system design process, the operator has been treated as a slack variable which could be exploited to overcome deficiencies in design. In today's complex weapon systems, it is imperative that the operator, as a subsystem, be considered explicitly on an equivalent level with, and developed concurrently with, other subsystems (avionics).

The Crew Station Integration Branch of the Human Engineering Division has pursued a research program seeking to balance the development of human systems integration assessment technologies with their applications to real-world problems. Drawing on the operational and scientific and technical expertise of a series of military branch chiefs [Maj Lonnie Roberts (B-52 Pilot), Lt Col William Marshak (Psychologist), Lt Col Michael Eller (B-52 Radar Navigator), and Lt Col James LaSalvia (B-1B Offensive Systems Officer)], the branch has strived to combine a high degree of operational relevance with valid human engineering practices. Two major forces that have impacted the branch's research and development program are reduction in crew size (from the six-place B-52, to the four-place B-1B, to the two-place B-2) and evolution of systems-of-systems architecture by the warfighters (Figure 1-11).

Beginning with a two-place defensive station, made up of an Electronic Warfare Officer and Gunner, the conversion of surplus training assets into highly flexible research simulation facilities was successfully demonstrated by Earl Sharp. This approach preserves the accuracy of display and control arrangement and feel, while facilitating integrated performance and workload measurements. Simulation facilities for the B-52, the B-1B, and the B-2 aircraft were developed and employed by Earl, Brad Purvis,

Gil Kuperman, and other branch members in support of emerging operational requirements. These facilities were complemented by the development of the Strategic Avionics Battle management Evaluation and Research (SABER) simulation facility, which was specifically built to support exploratory development. SABER, conceived and guided by Gil and Denise Wilson, is unique in that it can be used to simulate a generic, multi-place aircraft (bomber, tanker, transport, gunship) or, with a different software load, can support exploration of Battle Management/Command, Control, Computers, Communications, and Intelligence (BMC4I) decision-making functions.

The branch research program has explored the impacts on crews of integrating advanced avionics into existing and maturing aircraft platforms (led by the above individuals and 1st Lt Mike Stratton, Maj Ed Fix, Capt Marie Gomes, Dr. June Skelly, Dr. Mike McNeese, Capt Stu Turner, Capt Scott Smith, 1st Lt Lawrie Hamacher, and 1st Lt Stephanie Lind), the human-centered design issues associated with a surviving/enduring mobile command post (Denise Wilson), and the validation of conceptual human-system integration designs (Brad, Earl, Gil, Scott, and Stu). The Crew Station Integration Branch has been highly successful in application research based on a simulate-before-you-fly risk and cost reduction philosophy. Laboratory research has been complemented by the active participation of branch personnel in field and flight demonstrations. These projects include the investigation of night vision goggles for the B-52 and B-1B aircraft, the integration of night vision sensors and target cuers for navigation and target acquisition aiding, and the investigation of crew/vehicle interface requirements for a single-stage-to-orbit hypersonic spaceplane.

The recent research emphasis in the Crew Station Integration Branch is on exploring the impact on crews caused by integration into the manned bomber fleet of gravity and precision-guided conventional weapons, the integration of on-board mission management avionics, and the integration of real-time intelligence into the cockpit capabilities. Innovative research paradigms are currently being developed which tightly couple rapid prototyping technologies to man-in-the-loop capabilities.

2. Design Tools, Methods & Technologies

The Human Engineering Division studies human adaptation to increasingly severe operational challenges and develops databases, methodologies, tools, and standards to help system designers take maximum advantage of human capabilities and limitations in the design and evaluation of complex human-systems. This includes data concerning perception, human performance, and the multi-dimensional size, shape, strength, and functional characteristics of humans. The objective of this activity has been to assist the acquisition community in the design, specification, and testing of Air Force weapons systems. The approach, described in more detail below, has been to provide information for design engineers that permits them to integrate human operators into systems in a manner that will maximize total system effectiveness.

Integrated Perceptual Information for Designers

Reliable data on human ability to acquire and process task-critical information is of prime importance to the design of effective human-system interfaces. While the research literature contains an immense volume of pertinent data, it has not been systematically considered in the typical design of human-systems. Though the nature and availability of these data are a key part of this problem, this lack of utilization can also be attributed to the basic skills and inclinations of designers, limitations in the available support environment, and constraints imposed by the design and acquisition processes. Beginning in 1980, a series of US/NATO AGARD-supported efforts directed by Dr. Kenneth R. Boff were initiated to aid the use of ergonomics data in system design. The goals of these efforts have been to (1) identify and

consolidate ergonomics data of potential value; (2) "human engineer" the representation of these data to enable their effective use by designers; (3) sponsor training to sensitize designers to the value and application of ergonomics; and (4) develop media options for aiding designers in the access, interpretation, and application of ergonomics data. These efforts at understanding and remediating problems in the transition of ergonomic research to applications have since coalesced into a new model for the communication of ergonomics data to practitioners, educators, and researchers. These efforts are summarized below.

Handbook of Perception and Human Performance: Attempting to use the research literature can be a formidable task. This is due, in part, to difficulties in retrieving and interpreting specialized data from the multitude of information sources distributed widely over a variety of report media. The first effort was to identify, collect, and consolidate performance data into a primary reference—the *Handbook of Perception and Human Performance* edited by Boff, Kaufman, and Thomas and published by John Wiley and Sons in early 1986. For this effort, a team was assembled made up of more than 60 recognized experts in 45 subareas of sensation, perception, information processing, and human performance.

Engineering Data Compendium: The objective of this effort was to speed up the transfer of human performance data to the designers of complex human-operated systems. The target users were system designers with little prior training and experience with ergonomics but with a need for reliable data to resolve trade-offs between equipment requirements and human performance capabilities. The product of this effort was a reference document, the *Engineering Data Compendium*, edited by Kenneth Boff and Janet Lincoln and published jointly by AAMRL and NATO in 1988. The Compendium provides comprehensive information on human capabilities and limitations, with special emphasis on those variables which affect the human's ability to acquire, process, and make effective use of task-critical information. Information was selected for inclusion into the Compendium on the basis of its practical potential for system design through an iterative process of review and analysis employing hundreds of subject matter experts and design professionals. Prospective entries were reviewed on the basis of statistical and methodological reliability, applicability to the normal adult population, and potential relevance to design problems.

Ergonomics in Design Short Course: A series of specially designed short courses and workshops were conducted with the goal of providing design professionals with strategies for the use of ergonomics data. These courses were designed around hypothetical, but realistic, human-system design problems which the individual lecturers and student teams systematically addressed in a workshop format. In 1986, this course was successfully offered overseas in Lisbon, Portugal; Athens, Greece; and Delft, Netherlands under the sponsorship of NATO AGARD.

Crew System Ergonomics Information Analysis Center (CSERIAC): In 1988, CSERIAC was established at Wright-Patterson Air Force Base, operated by the University of Dayton Research Institute, and managed by the Fitts Human Engineering Division. Crew system ergonomics information focuses on human and equipment characteristics that either enhance and support, or degrade and debilitate, human performance and well-being in complex tasks and activities. Over the past seven years, CSERIAC has actively supported research, design, and development of complex human-operated systems through on-call analysis and evaluation of ergonomics data and technology. Additionally, it has successfully accelerated the transfer of behavioral, biomedical, and engineering research to practical applications in the private and public sectors. It is presently under the expert administrative management of Dr. Lew Hann and Miss Tanya Ellifritt.

Computer-Aided Systems Human Engineering: Over a decade of research and development aimed at understanding and remediating problems in the transition of ergonomic data and models to application in the design of complex human-operated systems eventually coalesced into a new model of Computer-Aided Systems Human Engineering:Performance Visualization System (CASHE:PVS). CASHE:PVS version 1.0 was developed as a multimedia ergonomics database on CD-ROM for Apple Macintosh computers for use by human-system designers, educators, and researchers. Co-developed by a consortium of US Government agencies and NATO AGARD and managed by Donald Monk, it allows users to rapidly access ergonomics data and models stored electronically as text, tables, graphics, and audio. It contains a hypertext version of the Boff & Lincoln (1988) *Engineering Data Compendium*, MIL-STD-1472D, and a unique, interactive simulation capability: the Perception & Performance Prototyper (P3). P3 aids users in interpreting and applying ergonomics to their specific problems by enabling them to manipulate and directly experience alternative representations of the conditional variables associated with the archived data. The CASHE:PVS CD also features the state-of-the-art in information retrieval, browsing, and navigation (Figure 1-12).

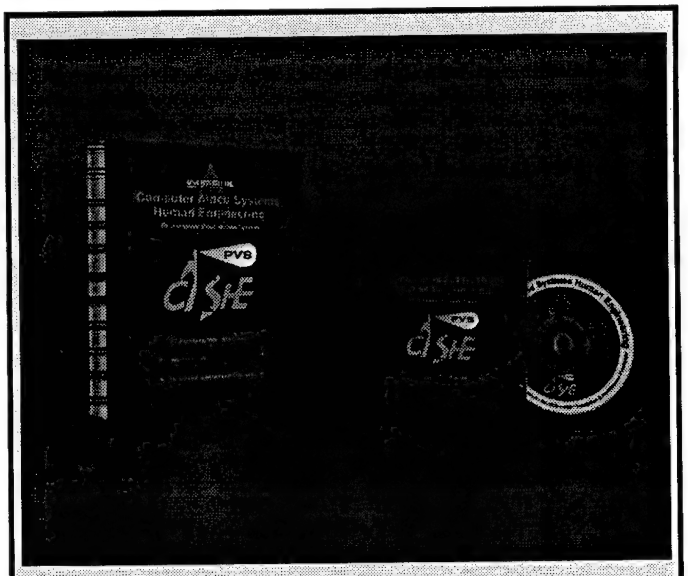


FIGURE 1-12: CASHE:PVS
The ergonomics design tool, CASHE:PVS, integrates interactive testbenches, audio, and animations, with text, tables, and illustrations so that designers can explore and experience the perception and performance data which are described in its reference documents. (Task 718412)

Anthropometric Modeling

The performance of Air Force aircrew members and support personnel is directly influenced by the man-machine interface. To optimize this interface, highly accurate anthropometry is required to define the shape and contour of the human body. As the Air Force's sole source of expertise in anthropometry, the Human Engineering Division provides state-of-the-art measuring techniques and novel statistical methods which optimize the integration of Air Force equipment and weapon systems to the human.

COMBIMAN is an interactive 3-D ergonomic computer graphics model of a human seated at a work station. It models male and female physical characteristics and was developed in the Human Engineering Division as an engineering tool for evaluating capabilities and spatial accommodation of the operator. In 1978, it was first transferred to aerospace industries. By 1994, much progress had occurred in COMBIMAN technology, and development commenced on creating a Virtual COMBIMAN that places a display viewer inside a 3-D cockpit drawing during vehicle landings. Thus, virtual COMBIMAN (Figure 1-13) is an application of virtual reality technology.

The development of CREW CHIEF (Figure 1-14), another expert anthropometric computer model and ergonomic engineering tool, this time for a maintenance technician, began in the division in 1984 in collaboration with the AF Human Resources Laboratory. An interactive 3-D computer-aided design (CAD) human-model of an aircraft maintenance technician, CREW CHIEF was developed by Dr. Joe W. McDaniel for use by aerospace manufacturers in designing crew station configuration. CREW CHIEF was interfaced with industry computer-aided design systems and, in 1988, it began to be widely used in the aerospace industry to evaluate equipment maintainability.

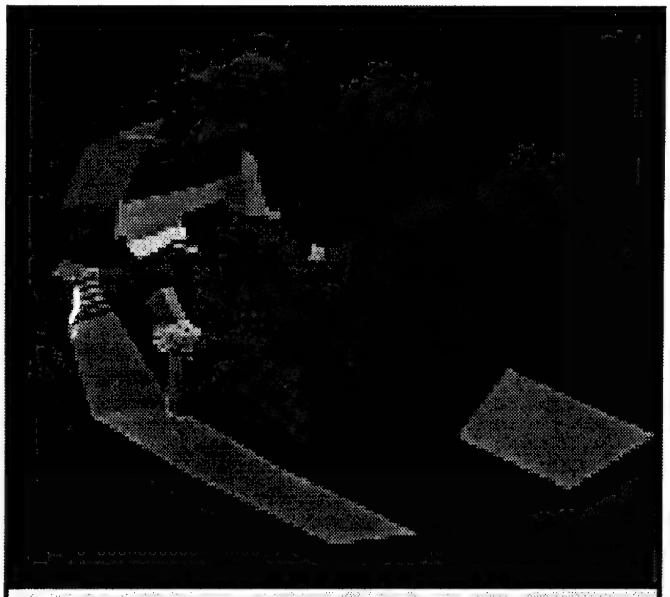


FIGURE 1-13: COMBIMAN

COMBIMAN creates a 3-D human model (male or female) together with six types of clothing, personal protective equipment, and three types of harness restraints . The user has full control over the size and proportion of the model, together with several computer-aided methods. Methods for incorporating the multivariate test sets, described above, are just one of many ways to dimension the model. Built in are models of male and female USAF pilots, non-pilots, and male and female Army pilots, per the latest 1988 survey. Strength analysis includes stick, wheel, lever, pedal, and ejection controls. Reach analyses consider clothing and harnessing for both reach to a specific control or a reach envelope (McDaniel, J.W., 1990). (Task 718408)

The above research and development work in physical anthropometry by personnel of the division's Physical Ergonomics Laboratory is only a small sample of the work done there in taking measurements of human physical dimensions, reach capability, strength and endurance, reaction time, time to perform tasks, etc. The laboratory has massive databases built on hundreds of thousands of measurements. These databases are often adequate for answering designers' questions. The Computer-Aided Workplace Design Facility of the laboratory is a network of computer work stations for developing and using expert ergonomics models, such as COMBIMAN, CREW CHIEF, and Virtual COMBIMAN, for visualizing physical performance in the workplace. When database entries and use of the computer models are inadequate for finding satisfactory answers for design questions, the rapid prototyping facilities of the laboratory allow it to quickly perform high-fidelity studies on task executions in work situations.

In the above discussion of physical anthropometry in the Human Engineering Division, it was noted that some of the technology of physical anthropometry, such as computer models, began in an earlier decade, and that development of the technology is still progressing. Figure 1-15 illustrates the chronology of important events, landmarks, and accomplishments in workplace technology resulting from the last 50 years of research and development work performed by the Human Engineering Division.

Engineering Anthropometry

The last decade has witnessed major technological leaps in the field of engineering anthropometry, and the Human Engineering Division has been at the forefront. The biggest innovations were in the areas of database systems, advanced statistical methods and applications, and 3-D anthropometric data collection.

Previously, the hundreds of anthropometric data collections were stored on shelves of magnetic tapes. During this decade, these were transformed into collated, searchable files on-line, and were made available off-site through modems. They were also integrated with statistical analysis tools that would enable the data system to actually write some of the analysis code. This work is still evolving with the development of object-oriented database software that will allow data to be stored and searched as objects, rather than individual elements, and with the rapidly changing Internet environments that are making information available to a much wider audience in forms easier to understand, visualize, and manipulate. This holds incredible promise for the next decade.

Analytic methods for anthropometric multivariate data representation, which were previously available only to the advanced statistician, were taken into the cockpit. Since the 1960s, gross errors, which resulted from the use of percentiles, had been demonstrated but remained in common use due to the complexity of alternative approaches. Figure 1-16 illustrates one of the problems with the

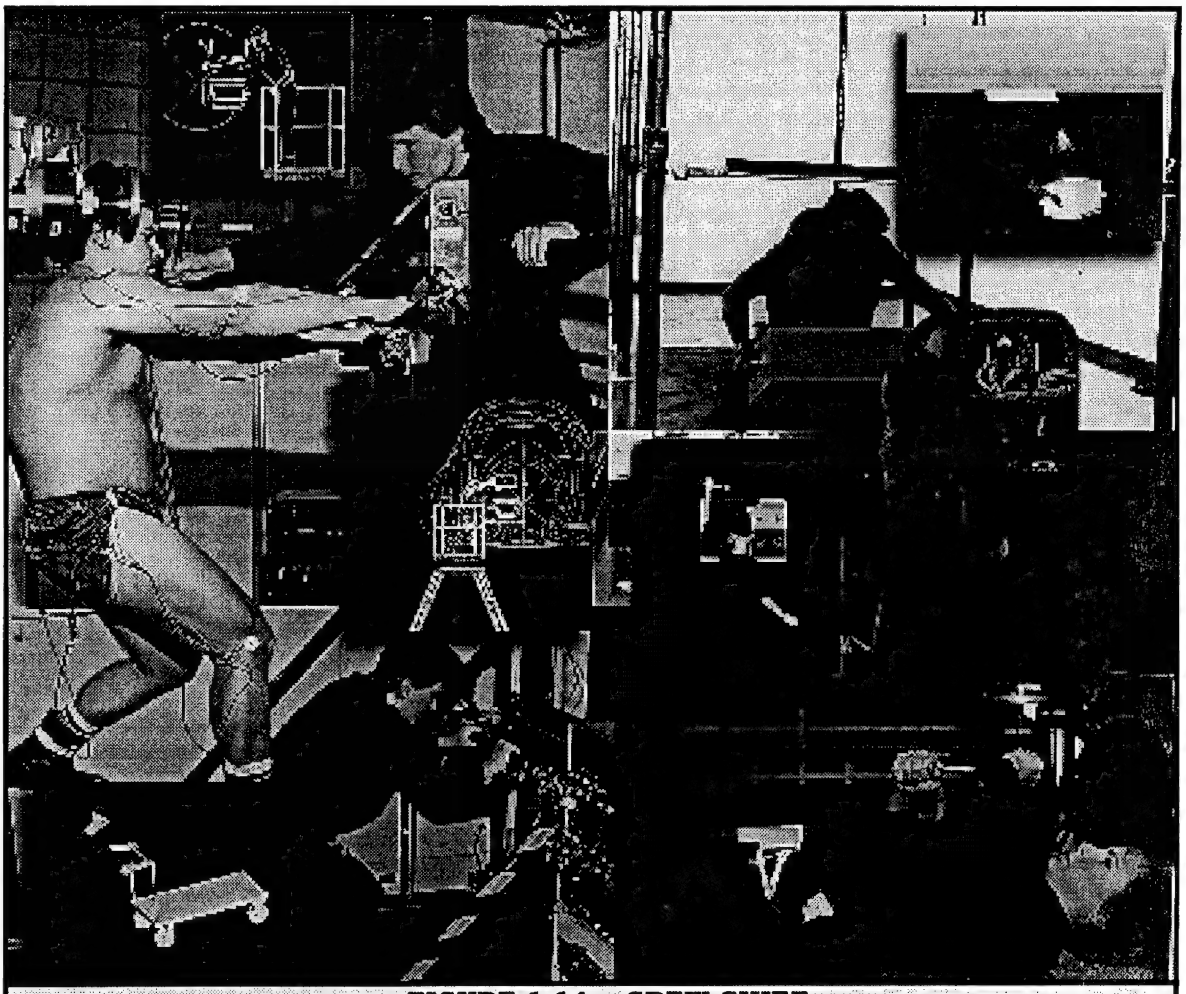
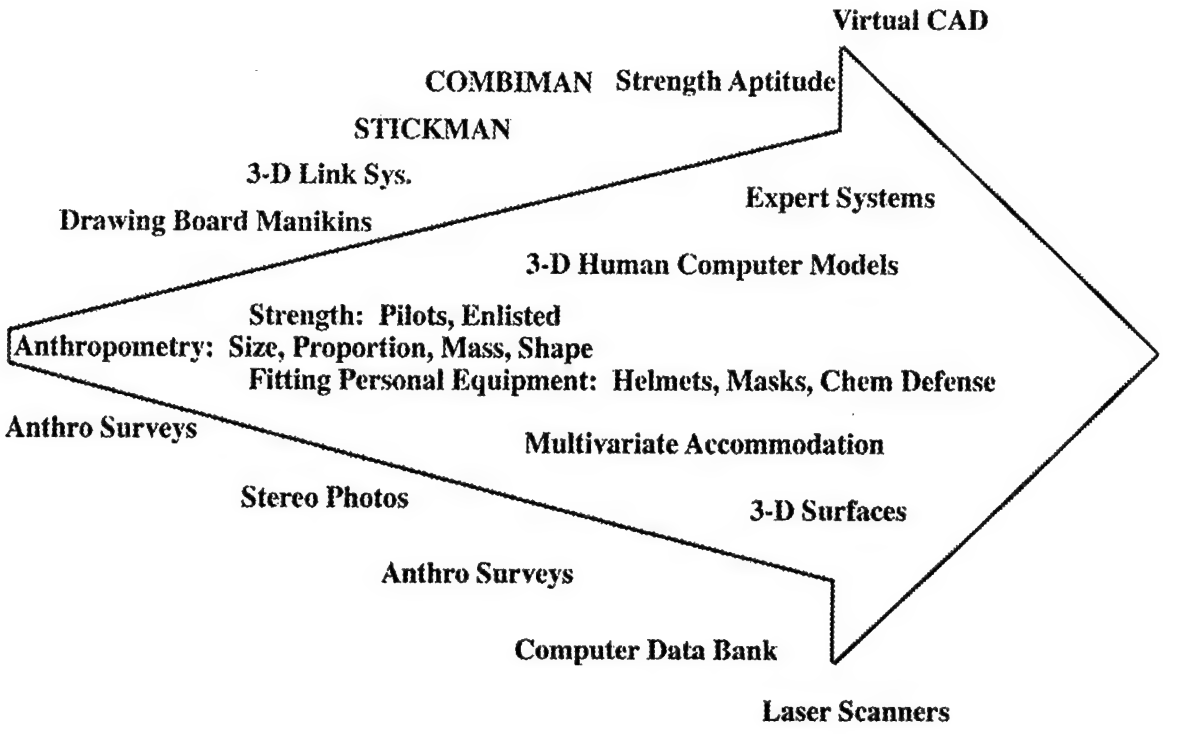


FIGURE 1-14: CREW CHIEF

CREW CHIEF, derived from COMBIMAN, automatically simulates maintenance activities, both with hand tools and materials handling (lifting, pushing, carrying, etc.), to determine if a maintenance activity is physically possible. Expert system software creates the 3-D human model with a full range of body sizes for men and women, the encumbrance of 4 types of clothing, 12 different maintenance postures, and a 222-piece tool kit. It automatically analyzes physical access for reaching into confined areas (with hands, tools, and objects), visual access, and strength. Visibility and task interference analyses can be computed with this "electronic mock-up" (Annis, J.F., McDaniel, J.W., & Krauskopf, P., 1991). (Task 718408)

use of percentiles and the magnitude of the impact from their use. As each new variable is designed or limited to just the 5th to 95th percentile, more and more people fall outside the accommodation range. The people who are extremely large or small for one variable are not the same people who are extremely large or small for another. Therefore, the more percentiles you use, the fewer people you accommodate. The purpose for using percentiles was to accommodate a particular percentage of a population. For example, the 5th and 95th percentiles were used with the intent of accommodating 90 percent of the population. This figure demonstrates that this is clearly not the case.

Greg Zehner, in 1992, demonstrated a practical implementation of an alternative multivariate approach, using principal component "cases" to evaluate cockpit accommodation. One of the first applications was in the acquisition of the T-1 aircraft. This acquisition was to be an "off-the-shelf" purchase, and manufacturers supplied their candidates for evaluation. After the multivariate anthropometric evaluation, it was determined that the otherwise best candidate would not accommodate 30 percent of white males, 80 percent of black males, and 90 percent of females who would qualify for flight training in the configuration presented. The cause was determined to be a problem with the



50 Years of Workplace Accommodation Technology

1946 - Strength for Aircraft Controls first measured in Paul Fitts division
1950 - Body size survey of 4,000 male pilots, 146 dimensions
1950 - 2-D Drawing Board Manikins depict range of body sizes for designers
1955 - 3-D Link System developed, relations between external flesh and internal joint centers defined
1957 - Masses of body segments for acceleration and crash test research
1958 - Stereo photography used in 3-D body size measurements
1959 - First general sizing system for flight clothing
1965 - Body size survey of 1,905 Air Force women, 139 dimensions
1967 - Body size survey of 2,420 male flight crew, 189 dimensions
1972 - STICKMAN is first human mel (stick figure) applied to first-generation computer-graphics displays
1974 - Strengths for aircraft control measured on centrifuge during high acceleration
1975 - COMBIMAN development began, 3-D computer model of aircraft pilot
1978 - COMBIMAN first transferred to aerospace industries
1978 - Female strength for operating aircraft controls first measured
1980 - Anthropometric relations with body segment masses and moments of inertia
1984 - CREW CHIEF model of maintenance technician began; interfaced to industry CAD systems
1987 - Strength Aptitude Test for all enlisted recruits approved by Secretary of Air Force
1988 - 3-D coordinates of head surface with laser scanner
1988 - CREW CHIEF first transferred to industry, began widespread use to evaluate maintainability
1988 - CARD dial-up body size database: Computerized Anthropometric Research Data
1994 - Virtual COMBIMAN Phase 1 puts viewer inside 3-D cockpit drawing during landing; variable sitting height
1995 - Multivariate accommodation technique used to evaluate JPATS trainer aircraft prototypes
1995 - Comprehensive male/female strength for all types of aircraft controls

FIGURE 1-15: WORKPLACE ACCOMMODATION

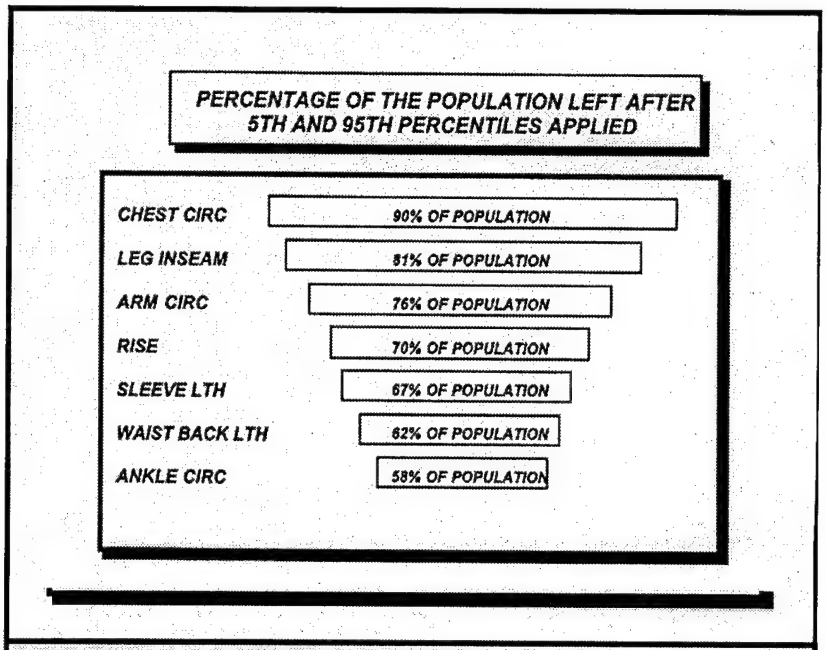


FIGURE 1-16 PERCENTILE VALUES
An illustration of the reduction in accommodation with each additional application of percentile values. (Task 718408)

yoke throw. This is pictured in Figure 1-17. This problem is manifested in those people who have short torsos and long legs or short torsos and large thighs. These represent combinations of small and large measurements which could not be characterized with percentiles and, thus, would not have been detected if only percentiles were used. In fact, we were told that the aircraft was designed for the 1st to 99th percentile pilot, and the manufacturer fully expected to accommodate at least 98 percent of the white male population. Since black males tend to have shorter torsos and longer legs than white males, and females tend to have shorter torsos and larger thighs than males, these groups were most affected.

That story ended well. Having identified the cause, the multivariate method also helped to identify the solution. The manufacturer was able to reconfigure the yoke to accommodate 99 percent of all of the eligible pilot populations.

Once the success of the multivariate approach for eligible pilots was demonstrated, the next question became, "who should be eligible pilots?" With Congressionally mandated policy changes on women in combat, the multivariate accommodation method began to be employed to evaluate accommodation beyond the former entry limit standard of 64-78 inches in stature and 34-39 inches in sitting height. This impacted the requirements for the Joint Primary Aircrew Training System (JPATS) Program, and anthropometric accommodation became one of the two highest selection criteria for that aircraft. Anthropometry, a term few people knew in the last decade, was for the first time being debated by Congressional staffers.

These developments were new and exciting, but perhaps the greatest change from the previous decade was the development and use of new automated 3-D surface scanning technologies for anthropometry. Some three-dimensional anthropometric data, collected prior to the mid-1980s, can be classified as two types: 1) measurement of a finite set of "homologous" points either statically or during motion, and 2) measurement of detailed points on static bodies. The former type of measurement requires a clear definition of all homologous points to be measured, referred to as landmarks, prior to measurement. On static objects, these points were measured mechanically by moving a stylus to each of the pre-defined (and often pre-marked) points and recording the stylus position. For example, Snyder, in 1972, used moveable scales and plumb bobs to record points on cadavers. Reynolds and Leung, 1983, implanted targets in unembalmed cadavers which were then captured with x-rays in stereo pairs. Gordon et al., 1988, used a mechanical stylus with a computerized 3-D locator for head measurement of living US Army personnel. A head box with a special clamp was used to steady the head as the stylus was moved from point to point.

Detailed 3-D measurement was limited to methods which did not automatically translate to geometric information, but rather the geometry had to be somehow manually extracted. One such method is stereo-

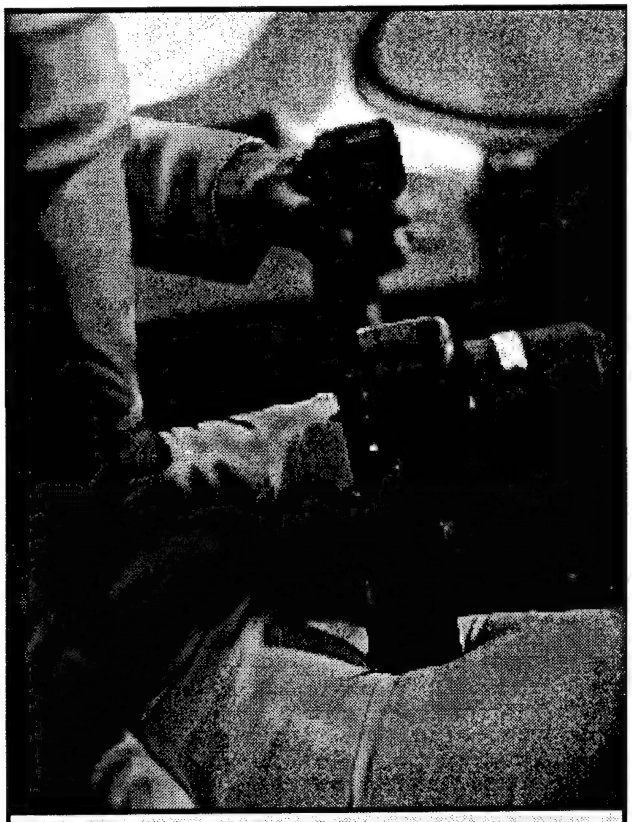


FIGURE 1-17: YOKE INTERFERENCE
Photograph of a pilot with yoke interference in the prototype T-1 aircraft. (Task 718408)

photography. Stereophotogrammetry basically captures the exterior surface with linked pairs of photographs. While it captured the images rapidly, the manual digitizing of the images was extremely slow. As a result, the number of subjects digitized in any one study was small; one set of studies which used stereophotogrammetry for estimating mass distribution properties of body segments measured just 31 men and 46 women.

New automated digital scanning technologies began appearing in the 1980s. The first one to be put to practical use was a head and face scanner produced by a company called Cyberware. Cyberware had developed a scanner for making realistic busts, much as portrait photographs are taken. It wasn't until they were approached by the anthropometry group at the Human Engineering Division that they considered it as a potential measurement tool. The anthropometry group worked with Cyberware to modify it for this purpose, adding a calibration tool and supporting software, for example. By 1987, the first head and face 3-D survey was completed at Wright-Patterson Air Force Base by the anthropometry group. In 1988, the scanner was taken on the road to three Air Force bases. This system is now the system against which others are compared. A photograph of the scanner is shown in Figure 1-18.

Automated 3-D scanning surmounts several problems inherent with the use of traditional anthropometry. For example, a nearly infinite number of contours can be derived from the traditional measurements; therefore, items produced by different manufacturers meeting the same anthropometry specifications can produce very different products in terms of shape and, ultimately, fit. In other words, due to anthropometry limitations, most of the surface of human models in the past has been filled in by artistic interpretation. This is true for ergonomic models such as COMBIMAN, CREW CHIEF, MANNEQUIN, SAMMIE, and JACK; biodynamic models such as ADAM and VIP; clothing body forms; oxygen masks; face forms and head forms for helmets. Furthermore, recent helmet fit testing has revealed that human surface geometry data

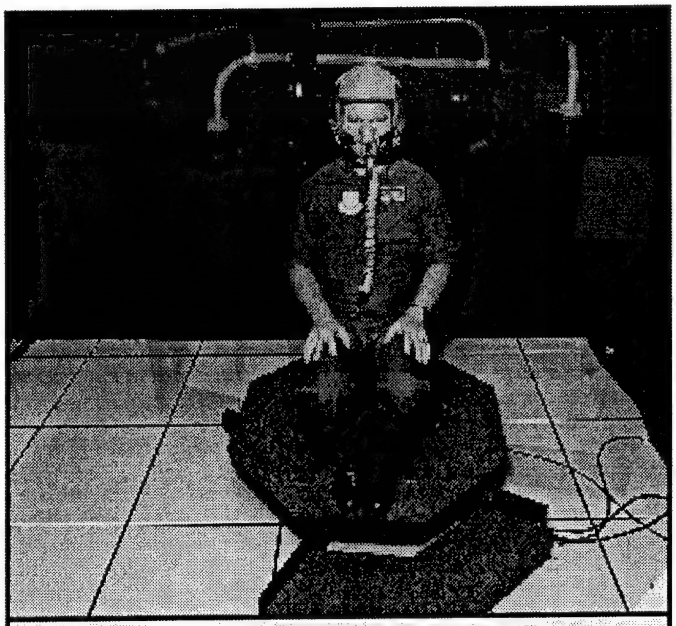


FIGURE 1-18: 3-D SCANNER
The automated 3-D scanner used in the first anthropometric scanning survey. Developed under a program managed by Kathleen Robinette, it was responsible for changing the field of anthropometry worldwide. (Workunit 71840850)

and the 3-D geometric link to the equipment are essential for understanding the underlying cause for fit problems and for quantifying and correcting them. As a result, knowledge of contour geometry can be critical to the success or failure of an equipment system. With the new automated 3-D scanning technology, it is possible to quantify the person and the equipment in 3-D space for the first time.

This new technology also makes it possible to exploit the power of new rapid prototyping and custom manufacturing technologies. For example, in 1995, a program was initiated to develop an automated method for producing custom-fit, positive-pressure oxygen masks. The ability to make prototypes quickly will reduce development costs by eliminating risk factors early in the design process. The ability to custom fit equipment will maximize accommodation levels, allowing accommodation of virtually 100 percent of a population. It can also reduce inventories and the cost of developing sizes for small percentages of the population. If effective, it can save billions of dollars.

The advantages of 3-D scanning are clear, and, in 1995, the Human Engineering Division acquired the first practical full-body 3-D scanning system and is planning the first international 3-D full-body survey. This will be a modern technology version of the NATO survey conducted by Mr. Hertzberg and associates in 1960-61. In the next decade it can be expected that this information, software tools, and application methods will be available on the information superhighway.

Crew-Centered Cockpit Design

Until the early 1980s, the laboratory did not have advanced development projects with which to demonstrate and mature its basic research and exploratory development products. The previous decade witnessed the emergence of high-technology sensors, weapons, and aircraft, which posed serious cockpit workload and safety concerns. The era also commenced a trend toward fewer crew members to lower acquisition cost, but that further aggravated the workload and safety concerns. Some systems emerging from flight test evidenced considerable cockpit-related design problems, requiring costly rework late in development. Senior Air Force leaders recognized that the Air Force lacked an advanced development project to focus the needed technology for the future (Figure 1-19).

In March 1980, the Air Force Systems Command directed the Air Force Laboratories to plan a new advanced development project for cockpit design technology. In response, a multi-laboratory working group (under a steering group comprising all AFSC Laboratory Commanders) planned the new project up to the point of a command decision to proceed. During the planning phase, the Air Force Studies Board (AFSB) convened a summer study at Woods Hole, MA in 1981 on "Automation in Combat Aircraft." The AFSB was an advisory group to the Commander of the Air Force Systems Command and comprised nationally renowned experts who made recommendations on topical issues. The 1981 summer study concluded that the Air Force should establish an advanced technology project to better organize how crew systems should be developed. The Studies Board met again in February, 1982, at Wright-Patterson Air Force Base, reaffirmed the summer study conclusions, recognized that the Air Force lacked an advanced technology project to focus this technology, and the AFSC Commander directed that the project be funded. Originally named Cockpit Automation Technology, the work was assigned to the Armstrong Laboratory and Human Engineering Division in 1982. The project was later renamed Crew-Centered Cockpit Design (CCCD).

The CCCD Project seeks to advance the state-of-the-art in crew system design technology, both for the process of design and for the tools that support the design process. The main products of the CCCD development are its highly disciplined process for cockpit design and a complete set of support tools and technology that will help to make the process efficient. Spanning all phases of system acquisition from concept exploration through production and deployment, the CCCD process is implemented on a computer design system having an integrated set of computer tools for crew system analysis, design, and test. Crew-centered cockpit design represents a new

capability for human systems integration, one that is compatible with and improves upon the current design practice. By designing the cockpit with the crew capabilities as the central focus, CCCD can maximize the air crew's ability to meet the challenge in future air operations.

In its first decade, the CCCD project directly influenced the way that crew systems are designed and acquired, in the aircraft industry and in DOD's acquisition and test agencies. Five of the nation's aircraft manufacturers participated in CCCD research and development contracts and continue to organize their crew system projects from a crew-centered focus. For example, Boeing replicated a version of CCCD's computer design system for use on its military aircraft projects, and McDonnell Douglas continues to maintain its own Advanced Crew-Centered Technology Project. Both are evidence of technology transition. The CCCD project published the first-ever industry survey of the cockpit design process and tools. The CCCD project participated in the F-22 development through a Memorandum of Agreement, contributed to its cockpit specification, was part of the System Program Office (SPO) Cockpit Working Group, and CCCD's crew-centered mission scenarios were the models for the design missions used in the F-22 demonstration/validation phase. The CCCD project advanced the recommendation to raise the reporting level of Crew System Development in the Work Breakdown Structure. The F-22 SPO, departing from tradition, adopted the idea and elevated its crew system team for better management visibility and influence. CCCD's published work on the organization of the design process both in industry and government was the model for the design process and detailed Crew System Engineering Master Schedule, both codified in MIL-STD-1776A, thereby affecting all future Air Force cockpit acquisitions. A particularly successful part of the CCCD project is its Test Planning, Analysis, and Evaluation System (Test PAES), now completing operational tests at more than 20 flight test agencies, including all of the USAF Combined Test Forces, Army and Navy test centers, and non-DOD customers, supplying an entirely new test and evaluation support capability for planning and performing cockpit evaluation.

3. Innovative Human System Interfaces

Visually-coupled, helmet-mounted technologies allow aircrews to operate in day or night environments, providing essential flight attitude and targeting information which permits off-bore sighting of weapons and sensors. Improvements in image intensifier technology will allow for the demonstration of Night Vision Goggles (NVGs) with a 60-degree field-of-view in 1995. While NVGs serve a

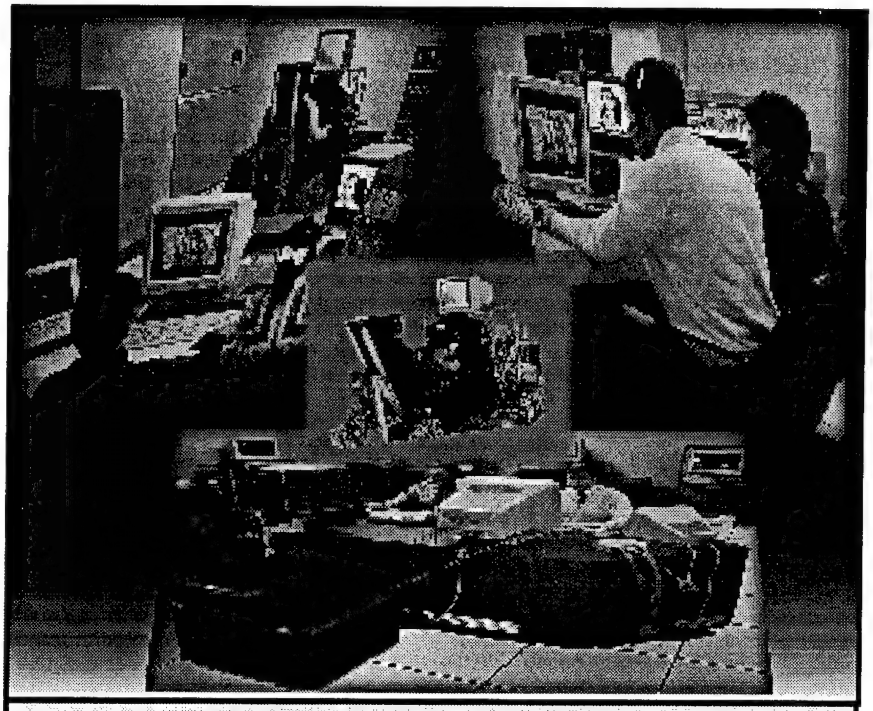


FIGURE 1-19: THE CREW-CENTERED RECONFIGURABLE COCKPIT Control, monitor and record real-time part-task, full-mission simulation. (Project 2829)

wide range of aircrew applications, the helmet-mounted display (HMD) that provides head-up display (HUD) symbology, forward-looking infrared (FLIR) and low-light level TV (LLLTV) imagery, or simple targeting cues, has a place in the high-performance cockpit as well as special operations aircraft. Critical technologies in the areas of three-dimensional audio localization, miniature video displays, and head trackers essential to an integrated helmet-mounted system were under development during this period.

Night Vision Operations and Aircraft Transparencies

The Human Engineering Division had its first exposure to night vision goggles in 1977, when it was loaned a pair of PVS-5 NVGs by then Major Robert Verona of the US Army for evaluation in possible Air Force applications. Two years later, in 1979, Human Engineering Division scientists, Dr. Lee Task and Leonard Griffin, were fully prepared to respond to the Military Airlift Command's request for assistance in modifying their HH-53H Pave Low III helicopter interior lighting to be NVG-compatible for the first time ever, thanks to the experience gained with the loaned PVS-5 NVGs.

This was the beginning of an expanding series of night vision operations projects, in direct support of a multitude of Air Force and Army NVG users, that came to full fruition during the 1985-1995 decade. Night Vision Operations activities have resulted in nine US Patents, with six other NVG-related inventions in patent-pending status. Under the expertise, innovativeness, and technical guidance of Dr. Task, there were numerous significant accomplishments during this time frame involving several key personnel. These include the developing, testing, and fielding of an NVG-compatible covert landing aid for landing cargo aircraft in austerely lit, potentially hostile environments (1982, Leonard Griffin); an NVG symbology overlay display, NVG-HUD, allowing the pilot to maintain an "eyes out" orientation during flight thereby decreasing workload and increasing mission safety and effectiveness (1982-1983, Leonard Griffin and Jeff Craig); low-profile NVGs offering a better center of gravity for paratroopers and possible aircraft ejection capability (1986, Jeff Craig); portable covert runway/taxiway marker lights for use with NVGs in both fixed and rotary wing aircraft (1987, Jeff Craig); NVG resolution charts for pre-flight optimization of NVG focusing (used in Operation Desert Storm-1990, Mary Donohue-Perry); NVG measurement methodology for assessing and validating NVG performance (1990-1995, Pete Marasco and 1st Lt Rich Hartman), a night vision ambient illumination tester for use in the laboratory or field to assess the degree of illumination present in a proposed NVG operating environment (1994, Dr. Alan Pinkus); and wide field-of-view NVGs offering a tremendous increase in the intensified night viewing area (1995, Jeff Craig) (Figure 1-20). Numerous other NVG-related human performance studies, aircraft lighting modifications, and technical consultations positioned the Human Engineering Division as one of the major forces in successfully transitioning night vision technology into Air Force operations.

During the early 1970s, the F-111 aircraft converted from thin glass windscreens to thicker plastic windscreens to improve birdstrike resistance. With this conversion came numerous new visual characteristics (Figure 1-21) of the thicker plastic windscreens, causing potential visual problems for the aircrew. Optical/visual windscreen analysis started at Brooks AFB, Texas, but, by the mid-1970s, transitioned to the Human Engineering Division. Initial activity centered around the visual problems identified with the F-111 conversion, which included multiple imaging, distortion, and haze. Multiple imaging was particularly disturbing during night landings in that the pilot would see two sets of runway marker lights due to the multiple reflections within the new plastic windscreens. Means of characterizing this effect and others are among the major accomplishments of the Human Engineering Division windscreen group during this time period (key personnel included Dr. Robert Eggleston, Lt Col Lou Genco, Dr. Lee Task, Bill Kama, Capt Mike

FIGURE 1-20: ADVANCED LOW-PROFILE NIGHT VISION GOGGLE (NVG)
Combining unique folded optics with high-resolution image intensifiers has resulted in a high-performance, ejection style NVG with a wide 45-degree field-of-view. (Task 718418)

Tutin, John Bridenbaugh, Harold Merkel, Dr. Alan Pinkus, and Pete Marasco). Standardized test methods for multiple imaging, distortion, haze, angular deviation, binocular disparity, reflection, and transmission were developed and published through the American Society for Testing and Materials (ASTM) for easy availability to both military and civilian applications. A total of twelve US patents, three other inventions still pending, and numerous human performance studies, presentations, publications, and consultations to both military and civilian organizations characterized this highly productive, successful program.

Visually-Coupled and Visual Display Systems

In this technology area, design criteria, component technology, and systems for visually-coupled helmet systems (VCHS) are developed on the basis of psychophysical theory and human performance data obtained in laboratory studies and on functional assessments during field evaluations under operational conditions. The state-of-the-art for VCHS was advanced by improved optical system and electronic circuit designs, hardware, and associated software. These improvements impact the performance and applicability of helmet display systems both militarily and commercially and allow research into the man-machine interface (MMI) to be pursued further than previously possible. Virtual display system component technology developments have been pursued under the Virtual Panoramic Display (VPD) program for transition to industry and the Armstrong Laboratory's Helmet-Mounted Sensory Technologies (HMST) 6.3A Advanced Development Program.

The Visual Display Systems Branch of the Human Engineering Division of the Armstrong Laboratory has played the key role in the development of helmet-mounted displays and sights and of visually-coupled systems. This technology is now used in many aircraft weapon systems and, increasingly, in other applications, both military and civilian. The division involvement dates from the mid-60s when Dr. Thomas Furness, Dean Kocian, James Brindle, and Charles Bates, of what is now the Visual Display Systems Branch, foreseeing the potential of the technology for improving the performance of military aircraft, initiated a program lasting decades to extensively develop it (See Table 1-3).

Over the past decade, the lab has focused on critical system and component tests and human factors experiments to solve the problems of integrating helmet-mounted display systems with the human visual system and advanced weapons systems. As evidenced by the many premier accomplishments shown in Table 1-3, the lab's research results have been successfully employed to optimize helmet-mounted display and miniature CRT phosphors, gun designs, and cathodes by investigating binocular vision, resolution, and contrast perception.

Dr. Brian Tsou led both equipment engineering research and human factors efforts involving the relationships between binocular helmet display design and visual performance of the human operator. In particular, he conducted research on binocular

TABLE 1-3 - Integrated Visually-Coupled Systems (VCS)/Night Vision History (29 Years of Armstrong Laboratory (AL) Leadership)*

YEAR	EVENT
1966	- First Remote HMS Development Inaugurated to Slew Sensors on B-50 Test Aircraft (Code Name: JB50).
1967	- Miniature CRT and HMD Development Initiated.
1968	- JB50 HMS System Accepted and Made Operational.
1969	- JB50 System Installed and Successfully Tested in Navy F-4B at Point Mugu NAS for Radar and Weapon Seeker Slaving Using Head LOS. - HMT and HMD Combined to Form First VCS (Precursor to All Subsequent Virtual Reality Systems). - HMS Pointing and Tracking Accuracy Study Initiated by AL at Tyndall AFB, FL F-101 and F106B aircraft.
1970	- First Direct Interface of HMS with Infrared Seeker Missile (AIM-4D) in F-106B with Live Fire Drone Shots and Kills Using Head-Slaved Seeker. - First Take-Offs and Landings Using Windowless Cockpit and HMD-External Camera Only Performed in F-100 at Kelly AFB, TX.
1971	- Visor Reticle Display for HMS Successfully Demonstrated by AL. - Advanced HMT Technology Development Begun by AL Involving Ultrasonic, Infrared, and AC Magnetic Technologies. - VCS Interface Successfully Demonstrated with Maverick Electro-Optical Seeker Head Prototype. - First VCS LOS Steering of Aircraft Using Head Motion Demonstrated by AL Personnel in C-131 Aircraft. - Tyndall AFB HMS Accuracy Tests Successfully Completed Resulting in Special Report ADC 69-19.
1972	- Visor Reticle Display and Infrared Tracker Technology Successfully Transitioned to Navy for Use in F-4 Retrofit Program. - Aiming of Aircraft Weapons Using HMS Demonstrated in C-130 Gunship. - Advanced HMT Technology Program Completed with AC Magnetic Approach the Clear Winner. - Program 5973 (Advanced Technology Demonstration) for Airborne-Qualified VCS Initiated. (Would later be Transferred to Aeronautical Systems Center in 1975) - First-Ever VCS Symposium Organized by AL and Held at Brooks AFB, TX. Papers Covered Head-Mounted Technology That Would Eventually Find Its Way Into Operational Use, as well as Virtual Reality Systems, Beginning in the Mid-1980s.
1973	- First Successful Visor-Projected Imagery Display Demonstrated for HMD Application. - First Successful Remote Oculometer System Demonstrated by AL Personnel. - Big Picture Concept Formulated. Essentially, the Concept was to Place Most of the HUD Information on the HMT/D System, Allowing the HUD to be Down-Sized, and Permitting Room in the Cockpit for Large Area Displays that Interacted with the HMT/D and Could More Effectively Present Global "Strategic" Information While the HMT/D Provided the Pilot with Near-in "Tactical" Information. - VCS Concepts Demonstrated With Long-Range Electro-Optical Seekers in Pave Scope at Edwards AFB, CA.
1974	- First-Ever Head-Steered Laser Designation Demonstrated in Pave Spike Program Using F-4 at Eglin AFB, FL.

YEAR	EVENT
1975	- Visually-Coupled Airborne Systems Simulator (VCASS) Program Initiated. Concept Involved the Design and Fabrication of a High-Resolution, Wide Field-of-View (FOV) HMD with High Resolution, Six Degree-of-Freedom HMT to Provide Scene Simulation with VCS Interactive Graphics Interface Overlay. Precursor to Modern Virtual Reality Systems.
1976	- Infrared HMT, Model 3 HMD Optics and Miniature CRT Technology Successfully Transitioned to Army Apache Program. - Advanced Miniature CRTs Developed for Use with HMDs.
1979	- Wide FOV (100°-140°) Partially Overlapped HMD with Successful Distortion Correction Demonstrated by AL Personnel. - First-Ever Demonstration of NVG with Compatible Cockpit Lighting Demonstrated in HH-53H Helicopter.
1980	- AL Personnel Complete Landmark Study Involving Incandescent Versus Electro-luminescent Lighting for Austere/Covert Runway Lighting to Support Covert Flight Operations.
1982	- NVG-Compatible Lighting Installed in A-10, AC-130H, and MC-130E by AL Personnel. - First-Ever NVG/HUD Designed and Built by AL Personnel and Installed on C-141B. - First-Ever Infrared Approach Path Indicator Developed for NVG Landings. - Full-Up VCASS Virtual Reality System Completed and Demonstrated.
1983	- AL Personnel Install NVG-Compatible Cockpit Lighting into CH-3, HH-53B/C, C-103E, and HC-103P. - NVG/HUD Installed and Flight Tested by AL Personnel on C-130E, MC-130E, and AC-130E Aircraft. - Day/Night Aerial Refueling Patent Employing NVGs Issued to AL.
1984	- NVG/HUD Installed and Tested on UH-60A, HC-103P, HH-53H, and HH-53B/C. - Virtual Panoramic Display (VPD) Program Begun in Support of Army LHX Helicopter Program. Essentially This Program Would Develop, Build, and Demonstrate Advanced VCS Technology to Support the LHX Night Pilotage FLIR. - Advanced Subminiature CRT Program Initiated for NVG/HUD and HMD Application.
1985	- First-Ever Diffuse Incandescent Runway Marker Light for Overt/Covert Operations and Glide Slope Indicator Demonstrated and Receives Separate Patents. - Advanced Subminiature CRTs Demonstrated for Use in NVG. Become DeFacto Standard for Narrow FOV HMT/Ds.
1986	- First Low-Profile NVGs Developed and Demonstrated by AL. - First DC Magnetic HMT Developed and Demonstrated in F-16 Attached to Green Mountain Air National Guard in Vermont.
1987	- NVG and NVG-Compatible Lighting Developed and Installed in B-52. - Advance "Box-and-One" Covert Landing Developed and Demonstrated by AL.
1988	- Unique "Contrast Sensitivity Function Measurement Chart" and Method Developed, Demonstrated, and Patented by AL. - AL Develops First-Ever "Deceleration, Prefocus Lens" Miniature CRT Able to Maintain Nearly Constant Line Width Over Large Beam Current Changes. - VPD HMD Prototypes Demonstrated to US Army Personnel. - Vista Sabre I Simulation Study Completed and Demonstrated Advantage of HMT/D Used in Conjunction with High Off-Boresight Angle (HOBA) Missile Seeker in Fighter Aircraft.
1989	- First Ultra High-Resolution Sputtered Phosphor Screen Developed and Tested in Miniature CRT. - Army Downselects VPD HMD Prototypes, for Which it Wants Flyable Brassboard Versions Built.

YEAR	EVENT
1990	- NVG-HUD Installed and Tested in MH-60J. - NVG Resolution Chart Perfected and Fielded On Short Notice for "Desert Storm" Operation.
1991	- Unique Robust Minimum Variance Linear Estimator (MVLE) Developed and Demonstrated for AC Magnetic HMT. - Unique Personal Illumination Marker Built and Demonstrated. - Vista Sabre II Program Initiated to Install HMT/D Systems in Two F-15Cs Located at Nellis AFB, NV.
1992	- NVG-Compatible Lighting Designed, Installed, and Flight Tested in B-1 Bomber. - First-Ever Course Prepared and Presented at SPIE International Symposium. - Miniature CRT Aviation Connector (AVCON) Demonstrated, Which Greatly Enhanced HMT/D Performance and Supportability by Fighter Squadron Personal Equipment Personnel.
1993	- Agile Eye™ Plus HMT/D Systems Successfully Integrated and Flown in Vista Sabre II. - AL Personnel Help Navy Initiate Their Own Vista Sabre Program Using F-18 and F-14. - NVG Low-Profile (Concept VI) System Demonstrated. - Unique Ambient Illumination Tester for NVG Developed by AL Personnel. - Programmable Airdrop Infrared Decoy Developed and Patented. - World's First Successful Mechanical High-Voltage, Quick-Disconnect Connector (QDC) for HMD Developed and Tested. - First "Standardized" Helmet-Vehicle Interface (HVI) Conceptualized. - World's First Miniature Subtractive-Color LCD Image Source Demonstrated.
1994	- Field Evaluation of NVG-Compatible Lighting Designs Evaluated for C-17, F-22, F-16, and C-130H3. - Wide FOV (Up to 60°) NVG (NOVA-8) Demonstrated. - Liquid Crystal-Based NVG/HUD Developed. - Agile Eye™ Mark III HMT/D System Flown in F-15C at Nellis AFB with Joint USN/USAF Developed HOBS Captive Carry Missile Seeker. - AL VPD System Delivered to Army and Used to Demonstrate Army's New High-Resolution LLLTV System at NVESD. - Visually-Coupled Acquisition and Targeting System (VCATS) Program Initiated to Develop Advanced HMCS for F-15C/D/E Aircraft.
1995	- Monochrome Field-Emitter-Array (FEA) Cathode Miniature Flat CRT Demonstrated. - Landmark Chapter on VCS Technology Written by AL Personnel and Entitled "Visually-Coupled Systems Hardware and the Human Interface," Published in Oxford University Press Book, *Virtual Environments and Advanced Interface Design*.

***NOTE:** Acronyms Used In Chart Are Explained Below.

VCS: Visually-Coupled System
NVG: Night Vision Goggles
HMT: Helmet-Mounted Tracker (head orientation and/or position)
HMS: Helmet-Mounted Sight (HMT plus fixed sighting display)
HMD: Helmet-Mounted Display (display only - doesn't include HMT)
HMT/D: HMT plus HMD
NVG/HUD: NVG plus head-up display overlay viewed through NVG.
CRT: Cathode Ray Tube
HMCS: Helmet-Mounted Cueing System
LOS: Line-of-sight from head azimuth and elevation orientation.
HOBS: High Off-Boresight Seeker
HOBA: High Off-Boresight Angle

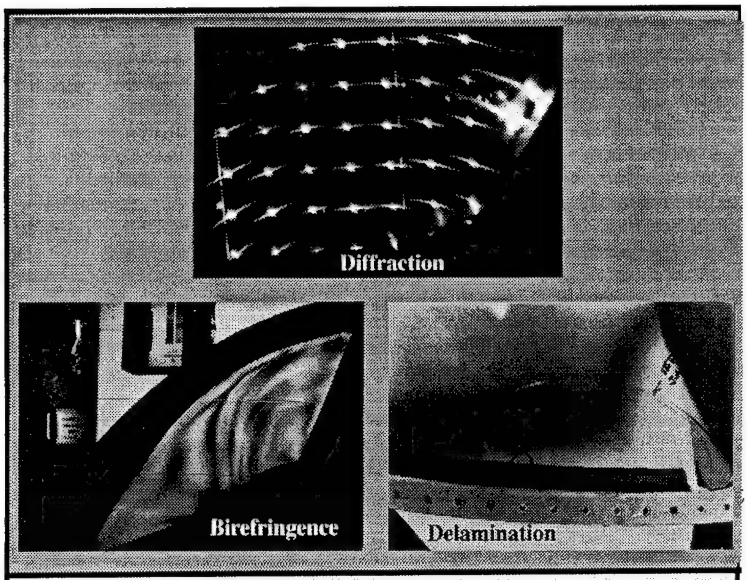


FIGURE 1-21: OPTICAL EFFECTS OF AIRCRAFT WINDSCREENS
Examples of some optical effects encountered in F-111 and B-1 aircraft windscreens. (Task 718418)

contrast sensitivity while using virtual image displays and generated binocular field-of-view requirements for the designing, building, and testing of next-generation, helmet-mounted displays. Two published studies have shown that the effective binocular visual field is about 40 degrees wide, and not the generally accepted number of 120 degrees, and that a divergent optics setup for overlapped binocular displays is superior to a convergent setup. Designers of Comanche helicopters have redirected their helmet-mounted display efforts to take advantage of these binocular vision research results.

The Visually Coupled Airborne Systems Simulator (VCASS) project directed by Dean Kocian began in 1977, as an effort to develop a fixed-base virtual environment simulator in which to investigate advanced airborne visually coupled concepts and their associated technologies. What set the Visually Coupled Airborne Systems Simulator apart from other fixed-base simulators was that all visual events within the simulation took place on a large field-of-view, partially overlapped binocular helmet-mounted display (HMD) that could generate 3-D stereo images and required special distortion correction to linearize the image viewed on the display. A six degree-of-freedom magnetic head tracker drove the scene presentation and allowed the parallax, due to head movements with respect to objects close to the observer, to be properly displayed. These advanced systems, when coupled with the wide field-of-view display system, resulted in a simulator that immerses the observer within an easily reconfigurable, computer-generated world, displayed relative to the observer's head movement (Figure 1-22). Since its initial demonstration, it has served as a bed for investigating visually coupled display perceptual issues and the applied evaluation of candidate helmet-mounted display symbologies designed for specific tactical arenas. During the mid-1980s, Michael Haas successfully employed VCASS to demonstrate advanced rotocraft displays and interfaces for the Army LHX Helicopter Program. Later, Dr. Robert Osgood systematically employed VCASS in the research, design, and evaluation of off-boresight helmet-mounted symbologies with the goal of enhancing pilot performance by providing information about critical flight status, weapons systems, and warnings, regardless of head orientation or movement.

Color display design criteria development was led by Dr. David Post, through work performed at the Color Display Laboratory (CDL). The increasing performance and diversity, and decreasing cost, of electronic color display technology create new demands and opportunities for exploiting color's advantages for conveying information. Effective use of color requires knowledge of display capabilities and human needs. The primary emphasis of the CDL has been on the production of devices, software, data, and mathematical models relevant to the design, evaluation, measurement, and use of color displays throughout the Air Force. These efforts have produced a high-resolution and high-brightness prototype Miniature Color Display based on stacking three monochrome liquid-crystal displays together and operating them in a subtractive-color mode. The resulting Miniature Color Display provides

daytime visibility with no resolution loss. Other products have included a high-efficiency, triband metal-halide lamp, a light-recycling pre-polarizer, and notch filter polarizers, all of which contribute significantly to the brightness of subtractive-color displays.

In 1993, the Vista Sabre II HMD Tech Demo Program retrofited two F-15Cs of the 57th Test Group at Nellis AFB with helmet-mounted display and head-tracker systems for the evaluation of high off-boresight weapon system use in an operational environment. Managed initially by Maj Vince Parisi and Dean Kocian and later by Randy Brown and Dean Kocian, Vista Sabre II began as a Congressionally mandated special project to evaluate and demonstrate the effective use of helmet-mounted cueing systems and symbology in "fast jet" combat aircraft. Inputs from the combat pilots at Nellis allowed the Visually-Coupled Acquisition and Tracking System (VCATS) Program to be inaugurated in 1994 as a top-ten ranked Advanced Technology Demonstration Program for Air Combat Command. VCATS will demonstrate advanced helmet-mounted tracker, image source, helmet technology, and perhaps most importantly, concepts for a "standardized" helmet-vehicle interface (HVI) that will promote commonality between USAF and USN fighter aircraft platforms.

Virtual Reality/Super Cockpit

One of the most challenging new technologies for application in the crew station is use of synthetic environments (SE), or what civilians call virtual reality. Capitalizing on two decades of helmet-mounted display work, SE has risen to the forefront in night operations which have been employed in Panama and Desert Storm. The simplest forms are the night vision goggles worn by aircrews. These will be supplanted by head-steered forward-looking infrared (FLIR) and later by multi-sensor systems that automatically switch or correlate their information. Hearing and touch will be brought into play with three-dimensional sound and tactile feedback. Controls will include helmet-mounted sights, such as in the Apache helicopter, and later, virtual switches actuated by tracking hand and finger motion through instrumented gloves. SE will provide "natural" user interfaces and the ultimate capability of tailoring the cockpit in both displays and controls to mission demands and user capabilities. Evolution of virtual reality, or synthetic environments technology, has been accelerated by the Human Engineering Division's coordinated development of component technologies and the human engineering integration required of the overall system.

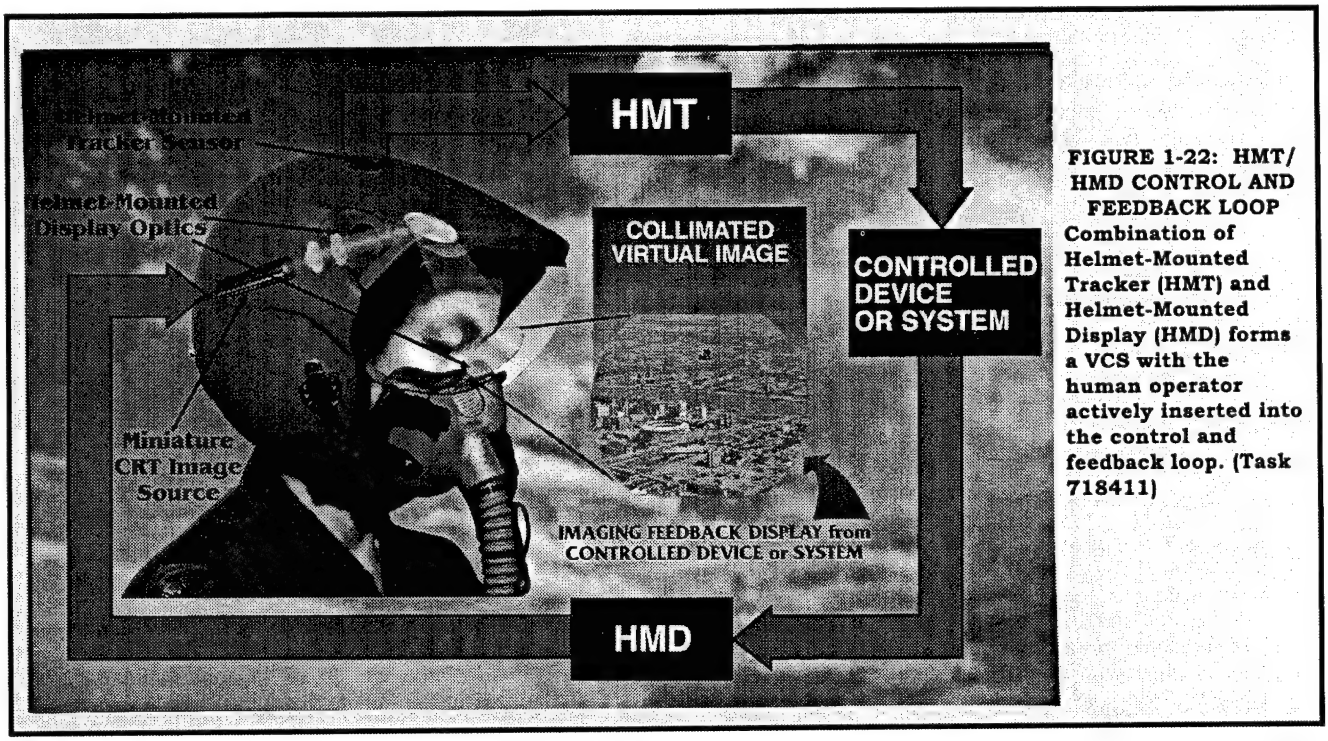


FIGURE 1-22: HMT/ HMD CONTROL AND FEEDBACK LOOP Combination of Helmet-Mounted Tracker (HMT) and Helmet-Mounted Display (HMD) forms a VCS with the human operator actively inserted into the control and feedback loop. (Task 718411)

The Super Cockpit Program was conceived under the visionary leadership of Dr. Tom Furness during Project Forecast II, which was an advanced planning exercise managed by the Air Force Systems Command in 1986. Dean Kocian, Michael Haas, and Dr. Robert Eggleston respectively, were selected to head up in-house hardware, software, and human factors R&D for the project. Dr. Wayne Martin played a key role in coordinating, managing, and documenting the myraid contacts and components of this complex R&D effort. The original concept was for "a revolutionary modular virtual crew station which communicates 3-D spherical awareness to the pilot or crew. Information from aircraft avionics, weapons, and sensors is fused, organized, and presented within a panoramic visual and auditory display surround for rapid assimilation by the pilot. The pilot directs weapons and commands aircraft systems by using line-of-sight, voice, and other natural psychomotor responses (Figure 1-23)". This program evolved into a 6.3 Advanced Demonstration Program, Helmet-Mounted Sensory Technology (HMST) presently managed by Randall Brown with Dean Kocian as Chief Engineer.

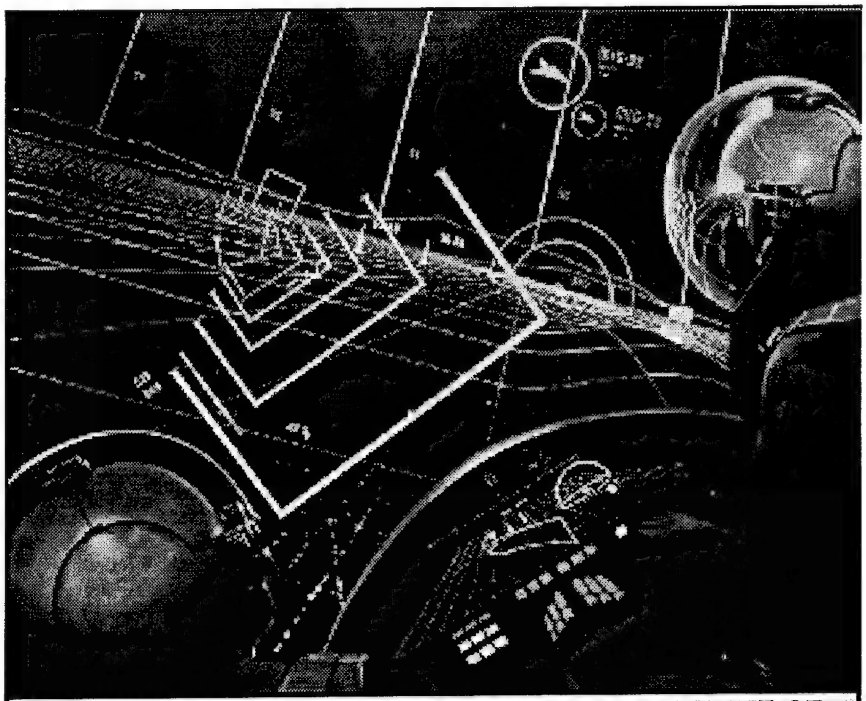


FIGURE 1-23: CONCEPTUAL DRAWING OF COCKPIT OF THE FUTURE

This widely disseminated artist's conception is a graphic portrayal of a virtual situation head-mounted display system for an encapsulated tactical environment. (Task 718426)

During Fall 1991, an international Super Cockpit program was formally initiated when the French and US Governments signed a Joint Memorandum of Understanding. The MOU involved three governmental organizations: the Human Engineering Division, Crew Systems Directorate of the Armstrong Laboratory at Wright-Patterson AFB; the CERMA in Bretigny, France; and the Section Etudes et Simulation, Centre D'Essais en Vol (CEV) in Istres, France. Nunn Amendment advanced development funding supporting the Super Cockpit Program began in December 1992. Dr. Kenneth Boff served as Program Manager and Michael Haas served as Technical Director and Chief Engineer.

The program was composed of two phases involving joint exploratory and advanced demonstration activity pursuing the design, development, and evaluation of control and display concepts utilizing multi-sensory, virtually augmented devices. The first phase consisted of the alignment of engineering research simulation facilities in the US and France. The second phase consisted of collaboration on the conceptual development and evaluation of virtually-augmented display and control concepts. During Phase One, Mike Haas, with the assistance of Chris Russell, directed the development of the SIRE Facility (Synthesized Immersion Research Environment) to create a synthetic environment for the rapid prototyping and evaluation of integrated virtual crew system concepts (Figure 1-24).

SIRE, which became operational in early 1994, consists of several autonomous research stations which can support individual research efforts or be combined to form a multi-participant virtual environment. One of the more striking research stations within the SIRE is a 40-foot diameter dome which includes a high-resolution, large field-of-view

FIGURE 1-24: SYNTHESIZED IMMERSION RESEARCH ENVIRONMENT FACILITY

SIRE facility (Synthesized Immersion Research Environment) provides a synthetic environment for research in visual performance, assessment of virtual design techniques, and the rapid prototyping and evaluation of integrated virtual crew system concepts. (Task 718419)

(70 degrees vertical by 150 degrees horizontal) interactive visual display driven by a Silicon Graphics Onyx computer image generator, with auditory displays capable of presenting simulated three-dimensional, externalized sound information, and an electro-hydraulic control loader system to provide augmented haptic cueing information. The Synthesized Immersion Research Environment lab is a general purpose research environment that can be configured to perform applied research on the design of advanced human-vehicle interfaces, including aircraft and ground vehicles. It can also be configured to perform more fundamental research on multi-sensory perception and human performance in virtual environments.

The VEIL (Virtual Environment Interface Laboratory) was founded by Dr. Robert Eggleston with the goal of providing technical data to characterize how humans perform in synthetic environments or utilize virtual devices in the performance of tasks. In support of the Super Cockpit program, Dr. Eggleston established bench-mark tasks that could be used to evaluate virtual system characteristics in terms of human performance applicable to a wide range of task conditions.

Alternate Control Technologies

Helmet-Mounted Oculometer System: In 1981, Michael Haas coordinated the receipt of residual equipment from Air Force Project 2360, managed by the ASD Simulator System Program Office. The key component of this delivery was a Honeywell helmet-mounted oculometer consisting of an infrared corneal reflection eye-tracking system and a magnetic helmet sight system. This delivery served as the impetus for a new research facility spearheaded by Dr. Kenneth Boff. The Helmet-Mounted Oculometer Facility (Figure 1-25) was established to capitalize on the Honeywell system's unique capabilities for unobtrusive and accurate monitoring of eye and helmet positions. In this regard, Mr. Haas managed the expansion of this residual equipment into a full-scale research facility, capable of measuring and recording eye and head data under experimenter-specified task paradigms.

Gloria Calhoun assumed responsibility for the Helmet-Mounted Oculometer Facility from 1983 to 1991. During the period, this facility examined the potential of using an operator's eye line-of-sight as an alternative control interface. Research determined the spatial/temporal parameters for implementing the eye-control algorithm and quantified the efficiency of eye control compared to other control mechanisms. Additionally, alternative eye monitoring techniques were evaluated in an effort to facilitate integration with visually-coupled systems and define performance parameters for airborne applications. The results of these research efforts paved the way for revolutionizing the interface between the pilot and aircraft. Use of eye control eliminates the need for a selective manual response by substituting the natural movement of the eyes which are inherent to the visual task. For tasks in which the pilot's attention is directed out of the cockpit, eye control could enable the control portion of these tasks to be completed with the head out of the cockpit.

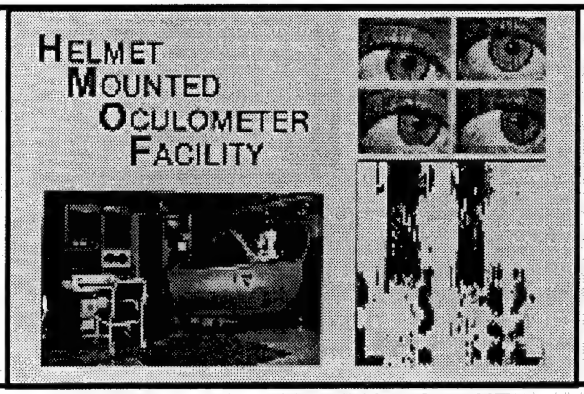


FIGURE 1-25: HELMET-MOUNTED OCULOMETER FACILITY
Both an eye tracker and voice recognizer were used to evaluate eye line-of-sight control with a verbal consent. (Workunit 71842602)

The Helmet-Mounted Oculometer Facility was also used during this time period to support other in-house research efforts. One was directed toward determining whether eye and head measures are valuable objective indicators of the effectiveness of attention cues and control/display design. Parameters of eye and head movements (e.g., sequence and latencies) were examined in comparison to the conventional performance index, manual reaction time, as a function of several factors: attention cue modality, task environment, attention allocation between tasks, and information location. In the case of cockpit design, this research suggests that these relatively nonobtrusive measures may be valuable indices for detecting a pilot's awareness of attention cues and changes in information presented. Another research effort examined the application of three-dimensional auditory signals to provide natural directional cueing. For example, the speed of target acquisition with a simulated aural directional cue was compared to conventional directional cues. The potential payoff of localized aural signals is the reduction in pilot workload together with an increase in situation awareness.

Brain-Actuated Control Research: This work grew out of research in the 1980s which examined the utility of the steady-state visual evoked response (SSVER) as an unobtrusive measure of cognitive workload. Subjects viewed a modulated light stimulus, and the brain response was evaluated as a function of the difficulty level of the primary task. Although this research did not show reliable sensitivity to task difficulty level, the variability in the SSVER data suggested that it was influenced by the subject's attentional state. To explore this further, a system was fabricated in 1987 to provide near real-time feedback on the EEG response to the evoking stimulus. The results of this closed-loop system still failed to show utility of the SSVER for workload measurement. However, subjects demonstrated their ability to regulate SSVER under various experimental paradigms, suggesting the exciting potential of using these brain responses as a direct link between mind and machine.

In 1989, Dr. Andrew Junker began to link the SSVER brain response feedback to a single-axis motion based simulator. Using biofeedback training, subjects learned to enhance or reduce the magnitude of their brain's response to a modulated light presented within a task display. These changes were then translated into commands that controlled the roll position of the simulator. The demonstration was a success, and subjects were able to operate the simulator using only brain-actuated control (Figure 1-26). However, it was evident control reliability and precision needed improvement before any application could be made.

In 1992, work resumed, under the direction of Maj Frank Fisher, to make significant system enhancements with the goal of improving signal acquisition and control efficiency. New control drive laws were developed for converting the brain response data into smooth, precise control signals. Ms. Gloria Calhoun assumed management of the effort in 1993, and directed the development of two new brain-actuated control task environments. In one, the brain-actuated control system was interfaced to a neuro-muscular stimulator, a device used to provide exercise for paralyzed limbs to illustrate potential rehabilitation applications of this innovative brain interface. In the second new task environment, subjects change the color of a displayed square to match the color of the square's border by modifying the magnitude of their brain response. This task environment is

currently being used in an effort to investigate the neurological mechanisms of brain-actuated control. Efforts are also underway to explore the utility of a brain interface for aircraft related tasks, such as radio and radar operation. This may be especially useful during high-G and high workload conditions.

A key to Armstrong Laboratory's advancements in brain-actuated control is the support provided by Dr. Grant McMillan. As manager of the Alternative Control Technology Program, Dr. McMillan has provided support and technological insight for system improvements and research direction. Moreover, Dr. McMillan can be credited with the significant publicity which the brain-actuated control program has enjoyed, including features in PBS's *Scientific American Frontiers*, ABC's *Good Morning America*, and CNN's *Future Watch* programs. In addition, this research has been highlighted in many publications, including *Discover*, *Air Force Magazine*, *Air and Space*, and *The World and I*.

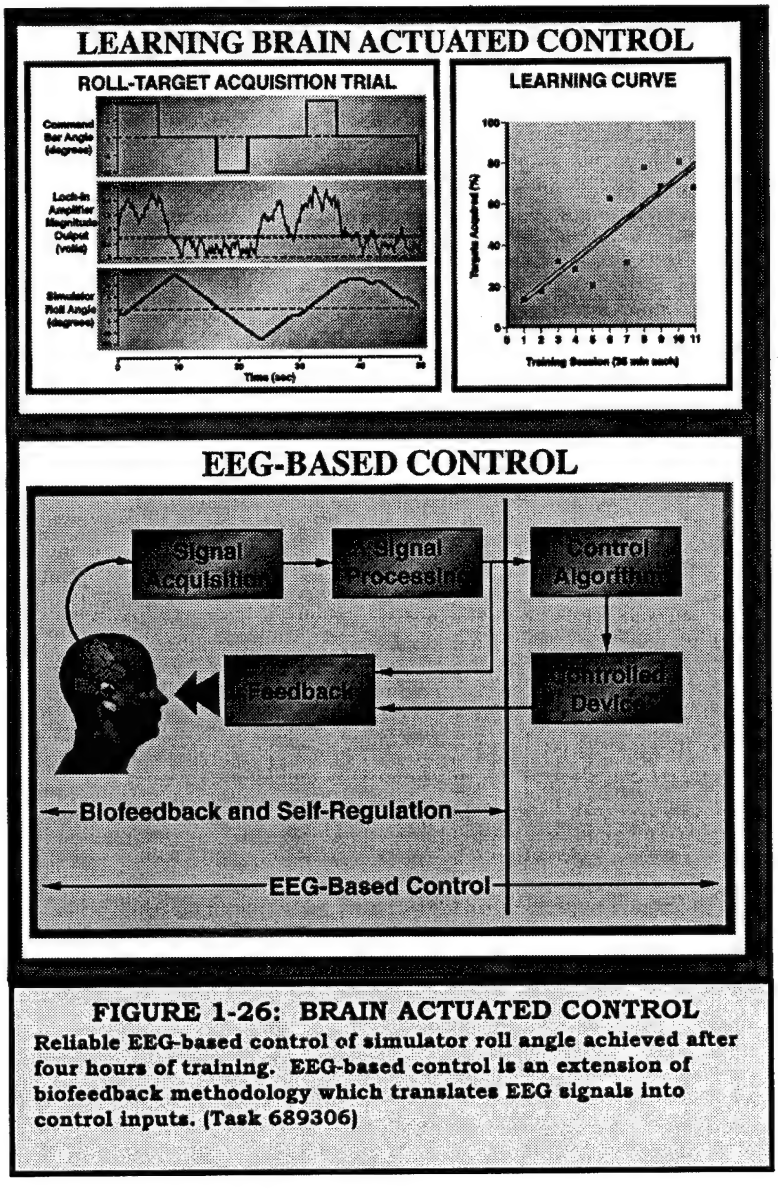


FIGURE 1-26: BRAIN ACTUATED CONTROL
Reliable EEG-based control of simulator roll angle achieved after four hours of training. EEG-based control is an extension of biofeedback methodology which translates EEG signals into control inputs. (Task 689306)

C. FACILITIES

In 1984, construction was completed on an extension to Building 248. This laboratory extension and accompanying modernization of the interior of 248 resulted in a doubling of available laboratory space to almost 70,000 sq ft. The resultant laboratory facility was primed to sustain its role as the pre-eminent human engineering research laboratory in the world. In 1985, the division was formally dedicated in honor of our founder as the Paul M. Fitts Human Engineering Division.

In January 1992, construction began on the Optical Systems Laboratory, a 200-foot long, self-supporting structure containing 14,500 sq ft of floor space joining Buildings 33 and 248 in Area B of Wright-Patterson Air Force Base. It contains five laboratories and has a horizontal window of special optical glass running its entire length, providing an unobstructed view to the West. Part of it is a structure resembling an airport control tower designed for tracking aircraft approaching the runway of Patterson Field in Area A. The tower facility will aid research in vision and the design and evaluation of helmet-mounted display systems, such as visually-coupled systems. It also has a spherical dome resembling a small observatory to be used for tracking aircraft and scanning the terrain. The new structure was completed in October 1993 (Figure 1-27).

D. ADMINISTRATION & MANAGEMENT

There can be little doubt of the value added from "50 Years of Human Engineering." The impact of our many technological successes and products has been felt and reported back to us from across the private and public sectors, around the country, and from many parts of the world. Less visible, but nonetheless a fundamental basis to these successes, have been the contributions of those professionals committed to the administrative and support functions of the organization. These include the branch chiefs, secretarial staff, technical editors, data processor managers, and administrators in accounting, contracting, personnel, travel, equipment, facilities, and support contracts. Though often unrecognized, these dedicated individuals collectively contributed greatly to the productivity, esprit de corps, and total quality of the divison and its products.

Take branch offices, for example. Made up of a branch chief and secretary, a successful branch office provides the full range of personnel, scientific, management, and support functions needed to allow branch members to be productive and to prosper. Branch chiefs generally are expected to split time between a full schedule of personnel duties and an equally full slate of technical duties—to be scientists, managers, leaders, motivators, disciplinarians, planners, and communicators. Secretaries, on the other hand, are expected to know how to do everything—and generally do. They are assigned a long list of duties, none of which captures the fact that they are primarily problem solvers and defacto assistant branch chiefs. Often they are the last link in the chain, the ones who get scribbled drafts at 3:45 P.M. that need to be in final form, coherent, proofread, and in ten copies by 4:00 PM. The finest secretarial work can easily go unnoticed because it tends to eliminate the problems and reduce the turmoil that normally command our attention.

The Human Engineering Division was graced over the last ten years, with a succession of branch offices of uncommon skill and effectiveness. The list below contains the names of prominent members of branch offices from that period arranged, roughly, by branch history.

Chiefs:	Secretaries:
Dr. Tom Furness	Tanya Ellifritt
Dr. Wayne Martin	Yolanda Crawford
Lt Col Mel O'Neal	Theresa Schiavone
Lt Col Mike Eller	
Capt Lee Penick	Cheryl Dunaway
Walt Summers	Rebecca Green
	Carole Patrick
	Sheila Radford
	Renee Kaffenbarger
	Anne Cato
Maj Lonnie Roberts	Sharon Sain
Lt Col Bill Marshak	Tina Sanford
Lt Col Mike Eller	Mary Louise Smith
Lt Col Jim LaSalvia	
Lt Col Lou Genco	Joanne Myers
Lt Col Al Dickson	Laura Mulford
Lt Col Mel O'Neal	
Dr. Grant McMillan	
Maj Ed Fix	
Maj Julie Cohen	
Maris Vikmanis	Marya Beverly
Dr. Clyde Replogle	Karen Unfried
	Betty Adams

The division office was equally blessed with gifted and tireless secretaries, including Barbara Osman, Suzanne Daly, and Betsy Combs. Each brought exacting standards to the job, thereby establishing and maintaining a tradition of business excellence. Their leadership has been invaluable.

Administration of the intangible resources entails personnel record keeping, budgeting, purchase request processing, expenditure tracking, STINFO, program and financial reporting, travel, manhour accounting, and several others. Originally administrated by the legendary Sandy Stevenson, these duties,

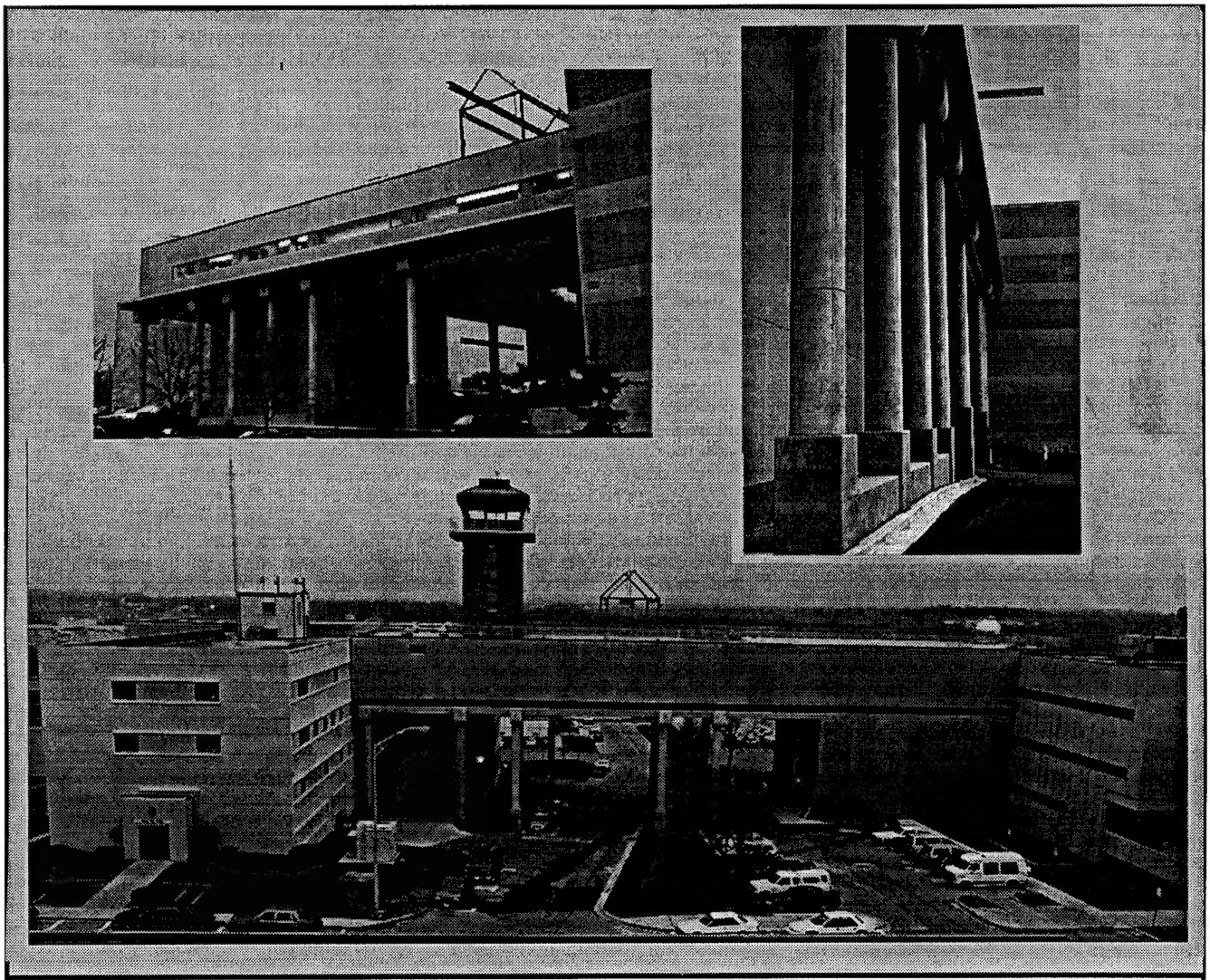


FIGURE 1-27: VARIOUS VIEWS OF THE HUMAN ENGINEERING DIVISION COMPLEX

swollen by ever-increasing reporting requirements, are now managed by the highly decorated, all-star team of Helen Redwine-Smith and Becky Green. The well-being of our tangible resources, e.g., our four primary buildings and their contents, was the responsibility of our real property managers, Al Chapin, SMSgt Dale Schimmel, and MSgt Bob Stewart. Each, during his tenure here, provided the Human Engineering Division with award-winning support. Two military construction projects and an in-progress, four-year infrastructure overhaul were handled with craftsman-like skill bringing the division's facilities in line with the finest in DOD. Mail distribution, travel orders processing, and similar duties were handled with dedication and superior know-how by TSgt Rob Johnson, SSgt Joe Gregory, and, more recently, SSgt Otis Newsome. A well deserved tip of the cap also goes to the really unsung heroes of the division--the managers of equipment and computer accounts, security, technical orders, hazardous material accounting, and many more.

Four contracts have provided broad technical support to the division over the last ten years. The largest, and most widely used, was held originally by Systems Research Laboratories (SRL), and now is held by Logicon Technical Services, Inc. (LTSI). During the majority of the ten-year span, these contracts were ably managed by Bob Linhart. With Bob's reassignment to another

division in early Spring 1994, management responsibility passed to our professional engineer, Bob Centers. When Bob Centers retired, the contract was passed to 1st Lt Bryan Christensen. Each of these managers served with distinction, making this contracted effort a support cornerstone of the division's research program and a model for all DOD laboratories. Much the same can be said about the success of Tom Green, Don McKechnie, and 1st Lt Bryan Christensen as managers of the division's strategic systems support contract with Scientific Applications International Corp. (SAIC) over the same period. Though somewhat less active, the rapid prototyping contract, held first by the University of Dayton Research Institute (UDRI) and BDM Corporation, and more recently by UDRI alone, was skillfully let and managed by Randy Yates. It provided off-site engineering services in the rapid preparation of prototypes of human-system interface components in a form ready for evaluation, such as flight test. Somewhat different is the CSERIAC (Crew System Ergonomics Information Analysis Center) contract, also with UDRI, but let through the Defense Technical Information Center (DTIC). One of only a score of DOD information analysis centers, CSERIAC is sponsored by the Human Engineering Division and provides the international human engineering community with a center of excellence in ergonomics and a gateway to ergonomics information and expertise worldwide. This ambitious venture owes much of its considerable success to a cadre of Air Force personnel, including Dr. Lew Hann as Program Manager, Tanya Ellifritt as Program Administrator, and Dr. Kenneth R. Boff as Technical Director.

The use of computers in the Human Engineering Division has followed closely behind the state-of-the-art, though remaining just far enough behind to ensure system reliability and full functionality. The first computer "network" connecting all members of the division computationally was designed by Bob Centers, assisted by personnel of Systems Research Laboratories. The system was a mainframe-based structure which provided electronic mail, file transfer, bulletin boards, and access to ARPANET, on a VAX mini-computer. The overall ADPE, or automated data processing equipment, program was managed by Walt Summers. In the early 1990s, management of the ADPE program was transitioned to Randy Yates, under whose insightful and energetic guidance (with support from Logicon Technical Services personnel), the system progressed to a full local area network, or LAN. Today's LAN offers full office automation, an inexpensive microcomputer-based architecture, full compatibility between Apple and PC computers, access to Internet, and much more. In a companion effort, Bob Centers and Randy Yates, with participation from Al Chapin, MSgt Bob Stewart, TSgt Wiley Wells, and others, developed an ultra-modern multi-media room which combines state-of-the-art audio and video presentation capabilities under convenient and powerful computer control—a conference room of the future.

SECTION 2 - 50 YEARS OF HUMAN ENGINEERING: BIBLIOGRAPHY

1945-1954 - The Foundations of Human Engineering

1955-1964 - Preparing Man for Space Exploration

1965-1974 - The Vietnam War Years

1975-1984 - Keeping Pace with the Avionics Revolution

1985-1994 - The End of the Cold War

About This Bibliography

The unclassified publications of the Human Engineering Division over the fifty years of its existence are presented in ten-year intervals in the present document. During this time period, the division participated in many projects that had security classifications as did the documentation about the work. The bibliography necessarily omits the titles of documents that had security classifications.

Some of the research and development work of the Human Engineering Division is published outside of the government in the journals and proceedings of scientific and technical societies and other organizations, and as chapters in books. An appreciable part of the division's work also appears in official publications of the US Government. These publications by the government include books, such as *The Engineering Data Compendium* and *Human Factors Issues in Head-Up Displays*, as well as handbooks and parts of handbooks, military specifications and standards, special reports and technical reports.

Technical reports are the Human Engineering Division's most common form of publication within the US Government. Prior to publication, these reports are reviewed by division personnel other than the authors, and permission to publish and release to the general public is granted only after examination by government personnel outside the Human Engineering Division. Technical reports by the division do not receive pre-publication peer review by individuals outside of the government, and division technical reports are neither as widely disseminated nor as readily available as journal articles.

However, technical reports are available to the public and have some advantages that sometimes make them a preferable form of publication. For example, there are no suitable journals for publishing tutorial reports, reports on research and development on military hardware, and extensive documentation on the data collections by the division's physical anthropologists on subjects such as human body dimensions and strength in executing various tasks. Technical reports can be considerably longer than journals will accept, hence they can report appreciably more details about the work. Technical reports permit publishing more pictures and other forms of illustration than are available in journal articles. Most of the pictures in the present document are excerpted from Human Engineering Division technical reports.

The designations of technical reports can be confusing to people not acquainted with them. In addition to their titles, government technical and scientific reports are identified by technical report labels. AAMRL-TR-89-001 is an example of a report designation. The title of this report is Display System Analysis for the LHX Helicopter Applications. Here, the letters, the alphabetic preface, designate the laboratory or other government organization that published the report. The TR stands for technical report, the first set of numbers identify the year that the report was published, and the last set of numbers designate the report's chronological order in the publication year. The translation of the designation of the above example is that the report was published by the Armstrong Aerospace Medical Research Laboratory in 1989 and is the first technical report for the year. The report numbers do not take into account journal articles or other forms of division publications within or outside of the government.

Since the laboratory name has changed over the years and since other government organizations sometimes have published works of the Human Engineering Division, the acronyms of the alphabetic preface of technical reports can be confusing and require clarification. Some of the more frequent acronyms used in the designations of division technical reports are as follows:

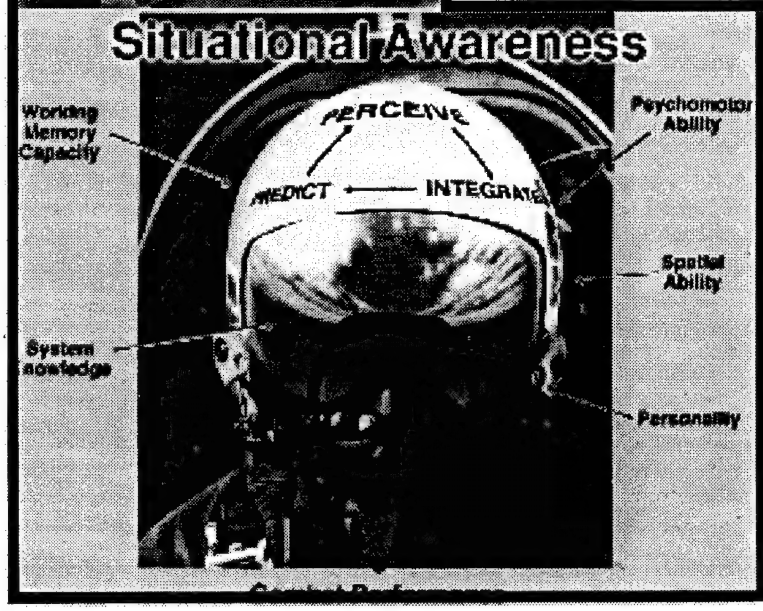
AF	**Air Force**
AAMRL	**Armstrong Aerospace Medical Research Laboratory**
AFB	**Air Force Base**
AL	**Armstrong Laboratory**
AMC	**Air Materiel Command**
AMRL	**Aerospace Medical Research Laboratory**
ASD	**Aeronautical Systems Division**
DTIC	**Defense Technology Information Center**
MRL	**Medical Research Laboratory**
TDR	**Technical Documentary Report**
USAF	**United States Air Force**
WADC	**Wright Air Development Center**
WADD	**Wright Air Development Division**

1945-1954

The Foundations of Human Engineering

1945-1954

World War II is winding down. Performance of many weapons during the war has been disappointing. Human failure is evident, but serious questions are raised regarding the suitability of the design of many of these weapons for human use. A 29 May 1945 Air Staff directive dictates "that facilities be established for conducting scientific psychological research on problems of aviation equipment" at Wright Field, Dayton, Ohio. The Psychology Branch of the Aero Medical Laboratory is born and with it the fledgling field of human engineering.



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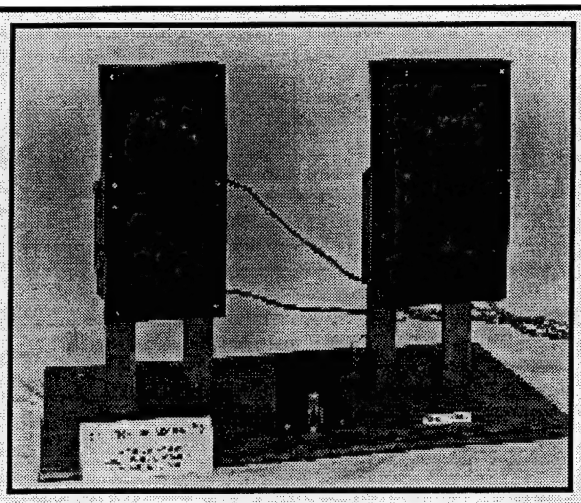

RELATIVE ROTATION DIRECTION OF DIALS AND CONTROLS

Determining the effects of the relative direction of rotation of dials and control knobs on the speed and accuracy of adjustment in alternating the positioning of two semicircular dial indicators with rotary knobs. This was one of four experiments described in the report by Melvin J. Warrick. AF Technical Report No. 5812 (1949)

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Lieutenant Colonel Paul M. Fitts, PhD
Chief, Psychology Branch

1945 to 1949

Lt Col Paul M. Fitts is generally regarded as the father of human engineering as a technical discipline.

He received degrees in psychology from the University of Tennessee (BS 1934), Brown University (MS 1936), and University of Rochester (PhD 1938) prior to being commissioned in the Army Air Force as a first lieutenant in the Aviation Psychology Program in April 1942. During most of the war years, he served as Assistant Chief of the Psychology Branch in the Office of the Air Surgeon, HQ USAAF. His major function was providing direction for the several field units of the Aviation Psychology Program.

At the end of the war in Europe, Fitts was dispatched to Germany for a three-month intelligence mission to investigate the Luftwaffe approach to the use of scientific psychology in support of military operations. In 1945, he developed a plan for a psychological research unit that would address man-equipment engineering design problems that underlie aircraft accidents, bombing errors, and other such phenomena that are evidence of human failures attributable to poor engineering design. The Air Staff approved his proposal on 19 May 1945 and he became the Chief of the Psychology Branch of the Aero Medical Laboratory. He served in this position until 1949.

His subsequent career included Professor of Psychology and Directorship of the Aviation Psychology Laboratory at The Ohio State University, Professor of Psychology and Head of the Human Performance Center of The University of Michigan, and membership on several research and development boards.

At the time of his death, on 2 May 1965, Dr. Fitts was serving as a National Research Council scientific coordinator for human performance issues relative to the Manned Orbiting Laboratory. Dr. Fitts' many contributions to the Air Force are well documented in both the scientific literature and in the methods, techniques, and disciplines applied today in the development of Air Force weapon systems. It was in light of Dr. Fitts' profound influence on the technology and programs of the United States Air Force and the Harry G. Armstrong Aerospace Medical Research Laboratory, that Building 248, Area B, Wright Patterson Air Force Base, was memorialized in his honor as the Paul M. Fitts Human Engineering Laboratory.

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What is now the Behavioral Sciences Laboratory began with the establishment of the Psychology Branch in the Aero Medical Laboratory at Wright Field in the closing days of World War II (August 1945). One of the first arrivals was Paul M. Fitts, then a lieutenant colonel, who was primarily responsible for organizing the new branch and served as its chief until 1949. Other psychologists among the initial staff were Robert M. Gagne, Walter F. Grether, Launor F. Carter, Judson S. Brown, John T. Cowles, William O. Jenkins, M.J. Warrick, Julien M. Christensen, A.P. Johnson, H.R. Van Saun, Glen Finch, and W.B. Webb. These and others among the early staff were members of the Army Air Force's Aviation Psychology Program, where they had worked on aircrew selection, training and rehabilitation. With the end of World War II many of the staff separated, and the branch became more stabilized with a staff of about 25 people.

— March 1965, "Human Engineering and Training Research Division," Behavioral Sciences Laboratory

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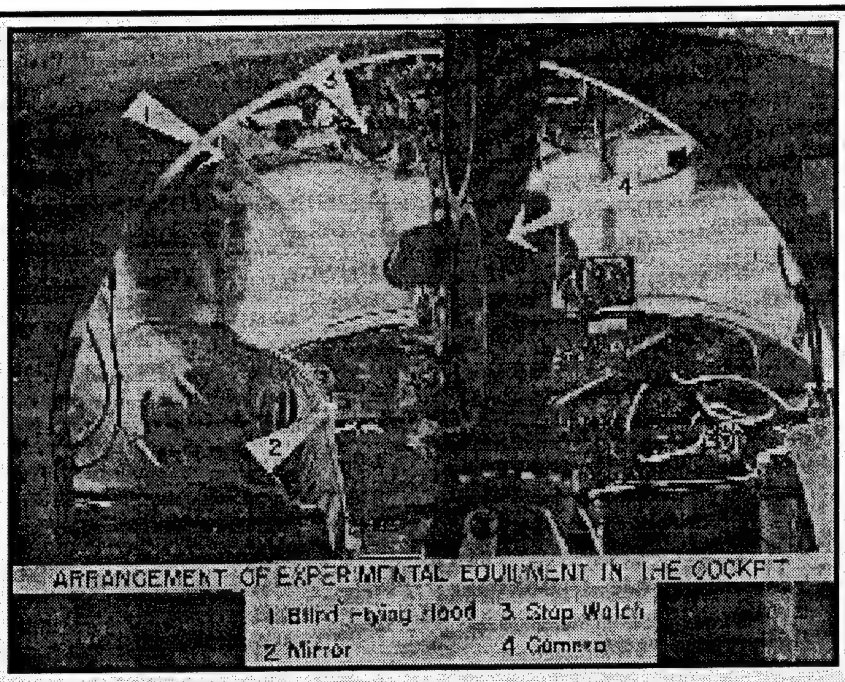
WORKSTATION DESIGN AND OPERATIONAL EFFICIENCY

Navigator working in C-54 cargo aircraft from a report on the activities of navigators in the Atlantic and Pacific areas. This work was part of a project in which data on the activities of crew members under operational conditions were collected to determine minimum crew requirements and to make changes in equipment and workstations to increase operational efficiency. Julien Christensen performed this research. AF Technical Report No. 5771 (1949)



RECORDING PILOT EYE FIXATIONS

Technique for recording the frequency, duration, and sequence of pilot eye fixations during instrument flight. This report describes the results of a series of related investigations conducted by the Psychology Branch. The report was authored by Capt Richard E. Jones, 1st Lt John L. Milton, and Paul M. Fitts. USAF Technical Report No. 5837 (1949)

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RELATIVE MOTION OF DIALS AND CONTROLS IN PURSUIT TRACKING

Measuring pilot performance in a pursuit tracking task with a crossed-pointer instrument used in some operational aircraft. The study determined the optimum direction of pointer motion relative to the movement of flight controls. The work was conducted by 1st Lt John F. Gardner. AF Technical Report No. 6016 (1950)

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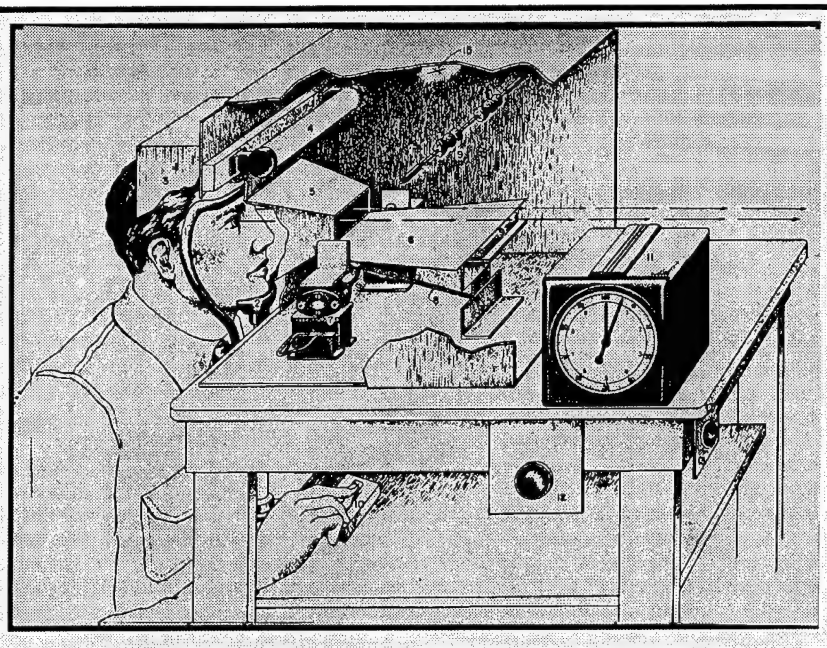

PAINTING AIRCRAFT FOR EASY VISIBILITY

Testing aircraft color markings for ease of detection to determine the most distinctive markings for operating in Arctic regions. The work was done by Capt Lawrence R. Wilcox and Dr. Walter F. Grether. AF Technical Report No. 5814 (1949)

Ellson, D. G. (1947). *The independence of tracking in two and three dimensions with the G. E. Pedestal Sign* (AMC Memorandum Report TSEAA-694-2G). Wright-Patterson AFB, OH: Air Materiel Command.

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As the Psychology Branch prospered, it also grew in size and in breadth of its responsibilities. Initially the branch had only three sections, one working on problems of visual displays, another on controls, and the third conducting flight research, first in a C-45, later in a C-47, and currently in a C-131 and two C-135 aircraft. In 1948, a new Systems Research Section was added, headed by Julien M. Christensen, now Chief of the Human Engineering Division. A Training Research Section was added in 1951, headed by Gordon A. Eckstrand. This has since grown into the Training Research Division. In the course of time other new activities were initiated which led to setting up new branches for "Maintenance Design" and "Environmental Stress."

— March 1965, "Human Engineering and Training Research Division," Behavioral Sciences Laboratory

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"One of the more unusual projects was flying in a wing-tip turret experiment. There was a pod out at the end of the wing on a B-17 where you sat throughout the flight. It was pretty frightening out there, with nothing but space on one side of you, and the realization that escape would be difficult, if not impossible. And of course, you always thought about the possibility that they would drag the wingtip on the landing. The data collected was mostly introspective—whether you could manipulate controls, whether the buffeting would be too severe, whether you would get sick. When I flew it was not particularly rough, but the wing still wobbled up and down a lot. I was in constant intercom contact, and if I had become sick, they probably would have aborted. Fortunately, that never happened. I don't think they ever pursued the concept of the wing-tip turret much beyond those early experiments."

"In a way, we initiated the area of man-machine dynamics modeling. With the publication of Wiener's book on cybernetics, Fitts interested one of the generals here on the base and the people at AFIT in the subject. Then I was sent to Europe to interview persons involved in the area over there. That was in 1947-48. I remember we sponsored the first seminars in man-machine dynamics, along with Frank Taylor of the University of Indiana. George Frost later wrote a nice summary of the area in the *Human Engineering Guide To Equipment Design*."

— Melvin Warrick, Associate Director Human Engineering Division

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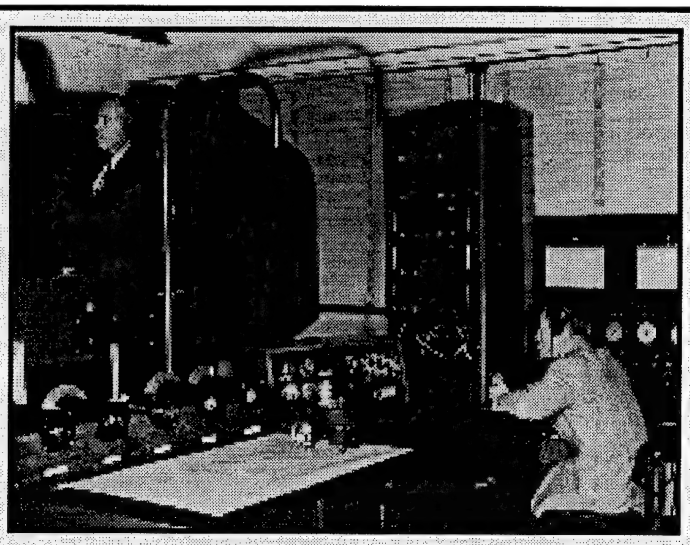

AN EARLY AIRCRAFT SIMULATOR
John F. Gardner serving as experimenter and Walter F. Grether serving as the subject in an aircraft simulator. Five different instruments are being compared for accuracy and reading speed. WADC-TR-54-236 (1954)

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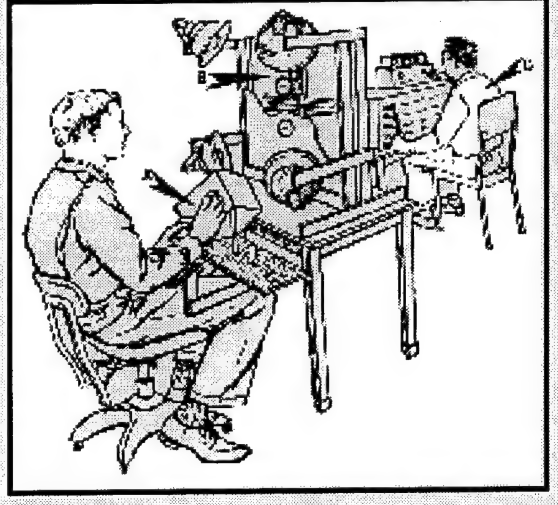

EFFECT OF DIAL SPACING IN PURSUIT TRACKING

Testing eye-hand coordination in a dual pursuit task in a study of the effects of arrangement of instrument pointers and the distance between them. The three experiments described in this report were conducted by Paul M. Fitts and Charles W. Simon. AF Technical Report No. 5832 (ATI No. 147788) (1952)

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Thus it came about that in late August of 1945 a group of us assembled at the Aero Medical Laboratory and set about the task of planning a new research program in Human Engineering. It was characteristic of Paul that he had things well thought out in advance. He had studied the statistics on aircraft accidents, bombing errors, and other evidence of human failures attributed to poor design. He was familiar with the wartime work of a few psychologists in this country and in Great Britain dealing with equipment design problems. He had thought of approaches, such as field studies, to obtain a better understanding of research needs. He had also thought of many experiments that were just waiting to be done.

—Walter F. Grether, Chief Psychology Branch, 1949-1956

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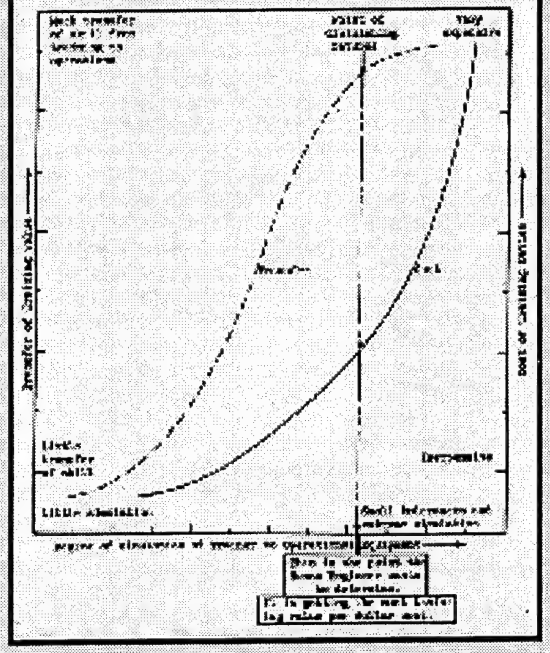

ENGINEERING SIMULATION AND TRAINING EQUIPMENT DESIGN

A graph of the relationship between degree of engineering simulation, cost, and value of transfer of training in training equipment design. This graph is from a handbook on training and training equipment design compiled by Robert B. Miller. WADC-TR-53-136 (1953)

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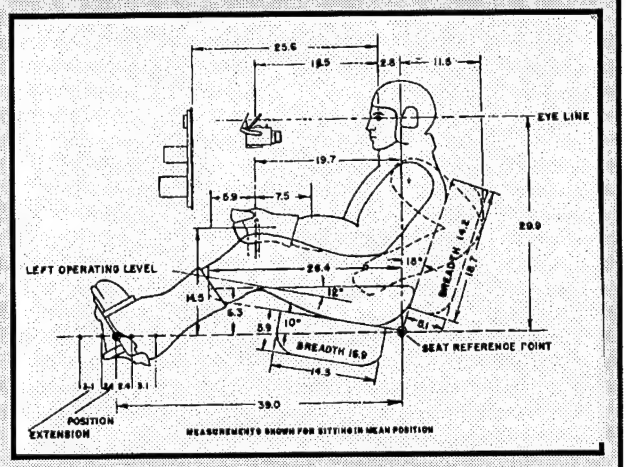
Fitts was an outstanding mechanic, and he knew how to design and, indeed, construct research apparatus of great delicacy and strength.

— Leonard Carmichael, Vice President for Research and Exploration, National Geographic Society, June 1965, "Paul M. Fitts Memorial Issue," Human Factors Society Bulletin



BODY SIZE AND PERSONNEL EQUIPMENT

Normal measurements for the pilot's seat in fighter aircraft from a Human Factors Division handbook on human body size and personnel equipment in military aircraft. The handbook was compiled by Capt Francis E. Randall, Capt Albert Damon, Capt Robert S. Benton and 1st Lt Donald I. Patt. Report No. 5501, Army Air Force Material Command. (1946)

Jenkins, W. O. (1946). *A Follow-up investigation of shapes for use in coding aircraft control knobs* (AMC Memorandum Report TSEAA-694-4A). Wright-Patterson AFB, OH: Air Materiel Command. (DTIC No. 105 851)

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Walter F. Grether, PhD
Chief, Psychology Branch
1949 to 1956

In July 1945, Dr. Walter F. Grether, Major, US Army Air Force, joined Dr. Paul Fitts in establishing the Psychology Branch, Aero Medical Laboratory, Wright Field, Ohio.

Grether and Fitts attracted such greats from the US Army Air Force's Aviation Psychology Program as Judson Brown, Launor Carter, John Cowles, Glen Finch, and Albert Johnson (and briefly, Robert Gagne and Wilse Webb). Grether stayed with the branch and replaced Fitts as the branch chief in 1949, a position he held until 1956, when he became the civilian director of the Aero Medical Laboratory's newly formed Behavioral Sciences Division. This division encompassed both the Engineering Psychology Branch under Julien Christensen and the Training Research Branch under Gordon Eckstrand.

During his 11 years there, the Psychology Branch engaged in a broad range of pioneering research, including fatigue effects during long duration flights, pilot error caused by non-standard control and display arrangement and shape, poorly designed altitude displays, and feasibility of seating pilots in the prone position. Grether also performed original research, such as his study of human errors occurring as a result of reading the standard three-point altimeter. The study provided a solid basis for his conclusion that errors could be greatly reduced by adopting a single pointer display. This type of display is now standard in most aircraft.

Grether retired from civil service in 1975 and the USAF Reserves as a colonel in 1976.

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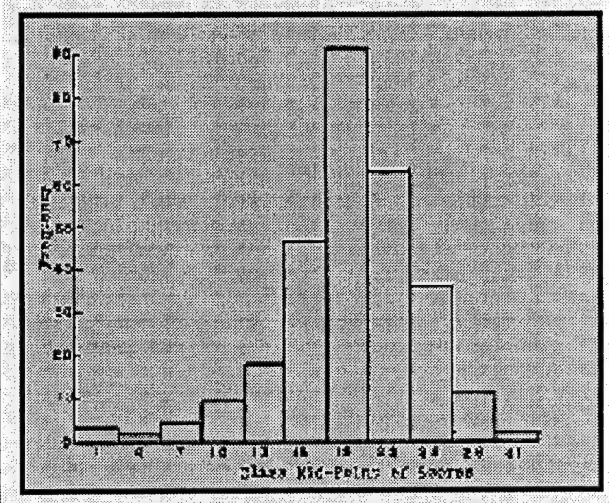
Kappauf, W. E., & Smith, W. M. (1948). *Design of instrument dials for maximum legibility: II. A preliminary experiment on dial size and graduation* (AMC Memorandum Report MCREXD-694-1N). Wright-Patterson AFB, OH: Air Materiel Command.



ASSOCIATING CLOUD TYPES WITH FLYING HAZARDS

Investigating the ability of pilots to associate flying hazards with cloud types. This work, part of an Air Weather Service Survey to help develop adequate weather briefings for pilots, was done by Lee E. Danielson, Julien M. Christensen, William R. Bastian, and Jean M. Ring. AF Technical Report 6687, Part 2 (1952)

Kappauf, W. E., & Smith, W. M. (1950). *Design of instrument dials for maximum legibility: II. Some data on the difficulty of quantitative reading in different parts of a dial* (AF Technical Report 5914(III)). Wright-Patterson AFB, OH: Air Materiel Command.

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29 May 1945...directive to the Commanding General, Air Technical Service Command, Wright Field, Dayton, Ohio . . . stating: "It is desired that facilities be established for conducting scientific psychological research on problems of aviation equipment. Because of the intimate relationship between psychological, medical, physiological and biophysical research problems, it is believed that this psychological research project should be established as a branch of the Aero Medical Laboratory."

— Air Staff Directive

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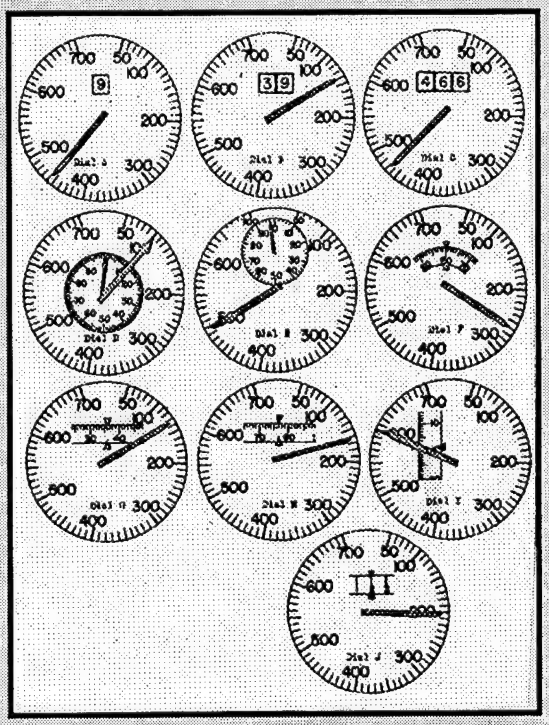

DESIGNING AIRSPEED INDICATORS FOR READING SPEED AND ACCURACY

Airspeed indicators used in a study comparing reading speed and accuracy to determine the best design for these instruments. The work was done by Maj George E. Long. USAF Technical Report No. 5836 (1949)

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The bitragion-crinon arc head dimension was one of 12 head size measures in a study that provided two nomograms for determining the most accurate estimate of each of the dimensions based on known values of head length, breadth and circumference. Study completed by Edmund Churchill of Antioch College and Gilbert S. Daniels. WADC-TR-53-14 (1953)

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Although engineering psychology had its birth during World War II, the level of research effort in the United States was on a modest scale until after the end of the hostilities in August 1945. This low level of effort was apparently deliberate, because it was recognized that only during a prolonged conflict could the benefits of such research be realized. Obviously, the time lag between initiation of engineering psychology research and the design, manufacture, and deployment of new or redesigned equipment is relatively long, often five years or more. Thus, during wartime, it was more profitable for psychologists to concentrate on other types of research, such as selection and training, with faster payoff.

—W.F. Grether, 1968, "Engineering Psychology in the United States," American Psychologist

Paul most certainly was among those engineers and scientists who served to give initial impetus and direction to an infant, interdisciplinary "human factors" area of endeavor. But without the wisdom, diligence, and dedication supplied by Dr. Fitts, human factors might not have survived its infant years.

— G.F. Rabidean, Editor, June 1965, "Paul M. Fitts Memorial Issue," Human Factors Society Bulletin

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"I was discharged from the US Army Air Force here at Wright-Patterson in March 1946. I had been working with the Aviation Psychology program while in the military. When I came on board Walt Grether was the Psychology Branch Chief and Julien Christensen was there, still in uniform. The actual staff at that time was just a handful of people. I had not known Paul Fitts, strangely enough, but he had been in Washington and, of course, knew about me. Chris and I had worked for the so-called "Trade Test" division—which was part of the Adjutant General's Office—on the problem of selecting aircrew and ground crew personnel. Chris was assigned here in uniform, and I had originally come here just to be discharged. But because the branch was here, and the work appealed to me, I stayed.

***

"My first project was the population stereotype for stimulus-response compatibility studies. Later, other people named parts of the results "Warrick's Law." I did the basic research then and Chris worked on applied problems."

***

"One of the more memorable people I worked with was Bill Biel. He came here after the war as my boss. He was most inspirational, protective, and friendly; the friendship continues to this day."

— Melvin Warrick, Associate Director Human Engineering Division

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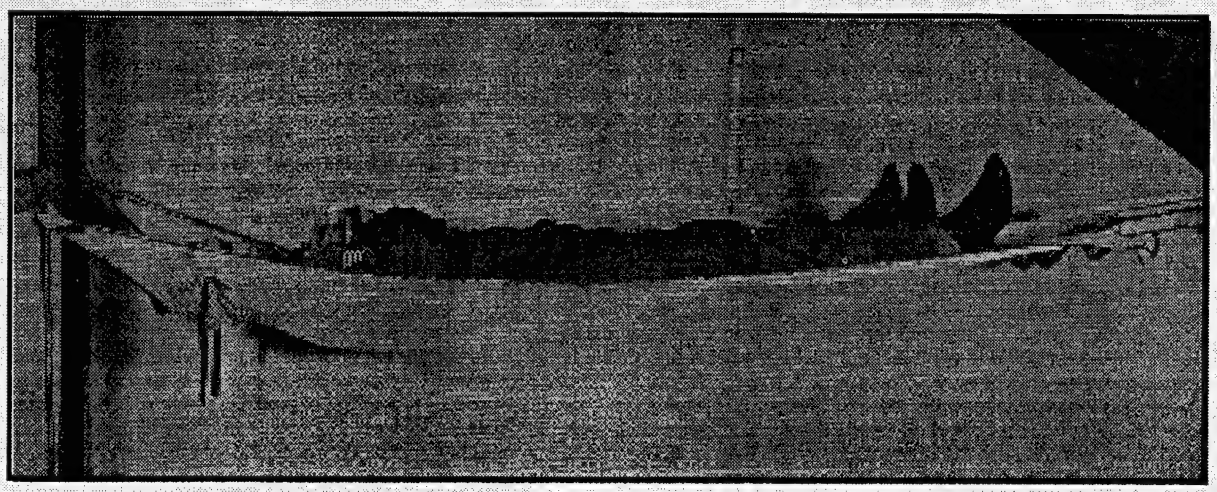
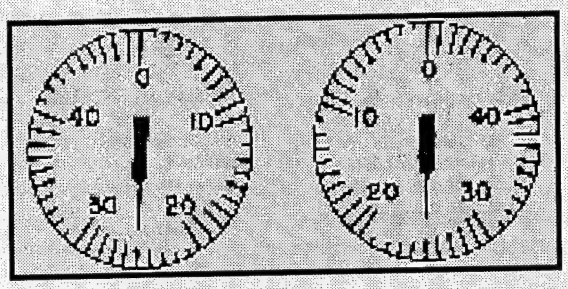


DESIGNING A HAMMOCK FOR BOMBER CREWS

A hammock for the B-36 aircraft designed with anthropometric data for Air Force crew members. The report contains detailed instructions for placing and installing the hammock. The work was done by H.T.E. Hertzberg and Gilbert S. Daniels. Memorandum report MCREXD-720-143 (ATI 122 733)(1949)



DIAL READING ACCURACY

Examples of staircase instrument scales used in a study of their effects on dial reading accuracy. The investigation was done because pilots were making dial reading reversal errors in reading a navigation plotter. The work was done by Julien M. Christensen. Memorandum report MCREXD-694-1-P (1948)

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"Many of Lt Col Fitts' early experiments dealt with the design of air crew stations...The controls and displays in WWII airplanes were similar in shape, design, and location. If a flight member mistakenly grabbed the wrong control, an aircraft accident or bombing error could result."

—C. Bates, May 1985
"Human Engineering, Yesterday and Today," Civilian Employees Reporter

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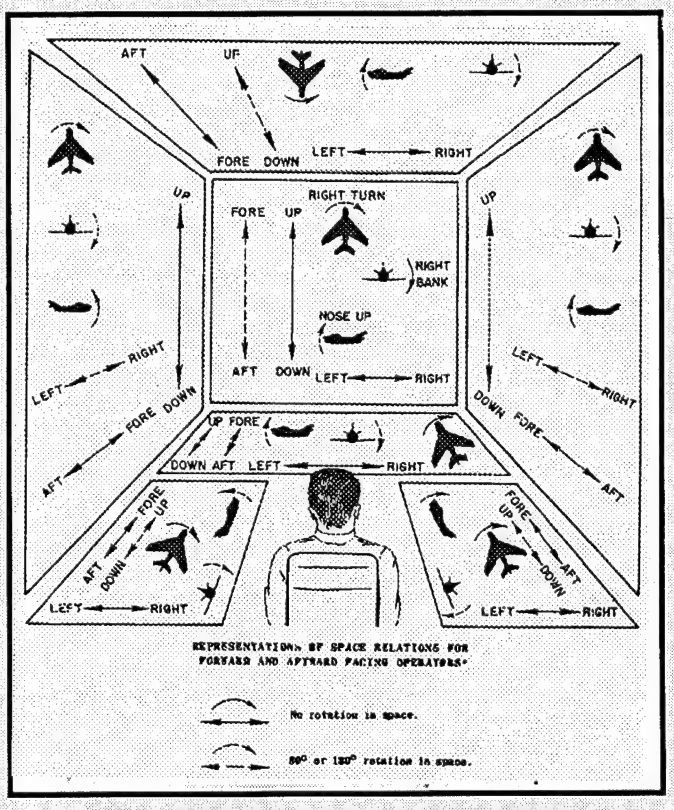

VISUAL PRESENTATION OF INFORMATION

Instrument panel layout representations for forward- and rearward-facing operators from a report on the visual presentation of information prepared under Research and Development Project Number 7180, Human Engineering Applications to Equipment Design. The authors were Charles A. Baker and Walter F. Grether. WADC-TR-54-160 (1954)

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I have never known any professional and fully scientific psychologist who excelled Fitts in his ability to explain the contributions of human engineering to modern military and space problems.

— Leonard Carmichael, Vice President for Research and Exploration, National Geographic Society, June 1965, "Paul M. Fitts Memorial Issue," Human Factors Society Bulletin

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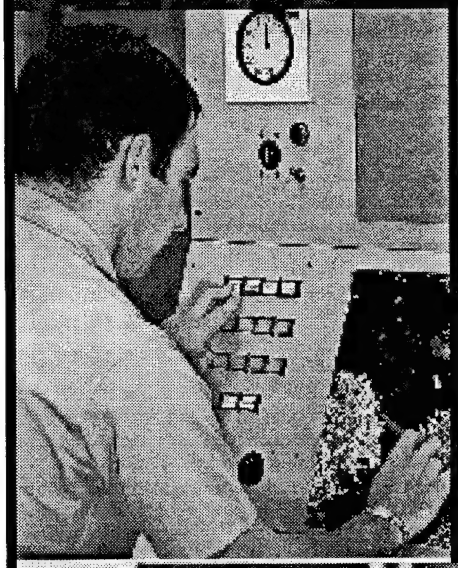
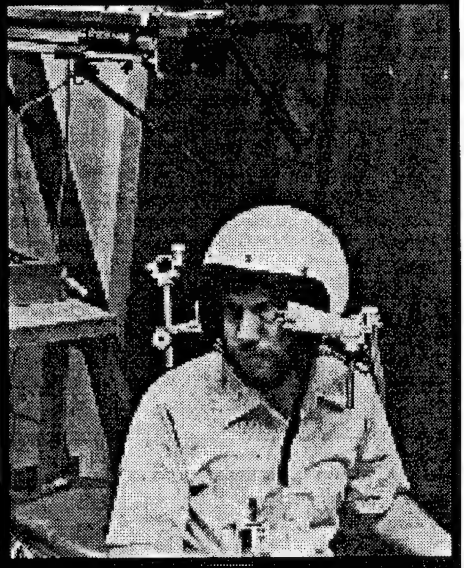
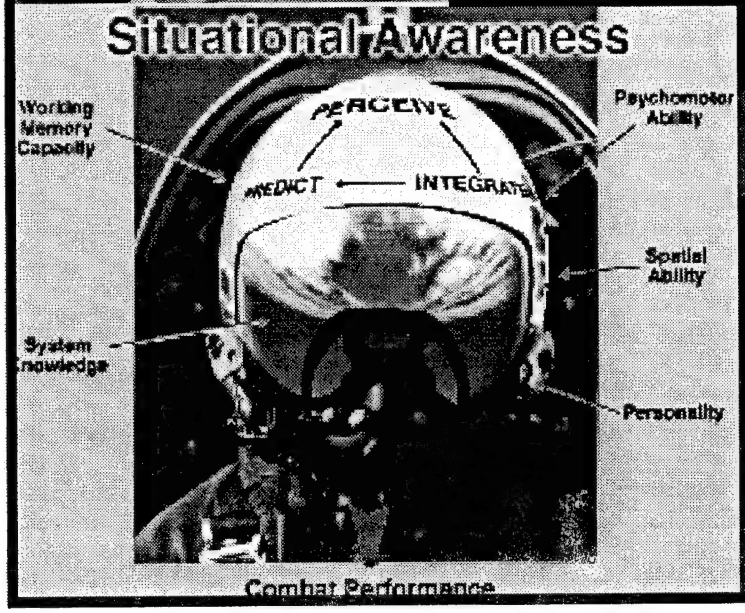
Preparing Man for Space Exploration

1955-1964

Sputnik will become a household word, and a daring young president challenges his nation to put a man on the moon and return him safely in the ensuing decade. The challenges are immense. Lt Col Fitts has left his indelible stamp of excellence on the Psychology Branch and moved on. The Grether years further fanned the flames of scientific excellence. The future of the Human Engineering Division is now turned over to Dr. Julien Christensen, ably assisted by Dr. Melvin Warrick.







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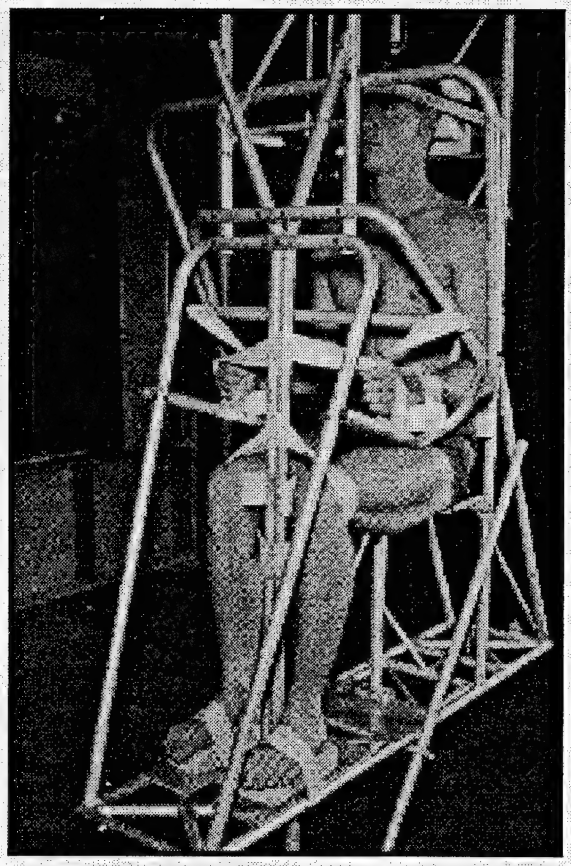
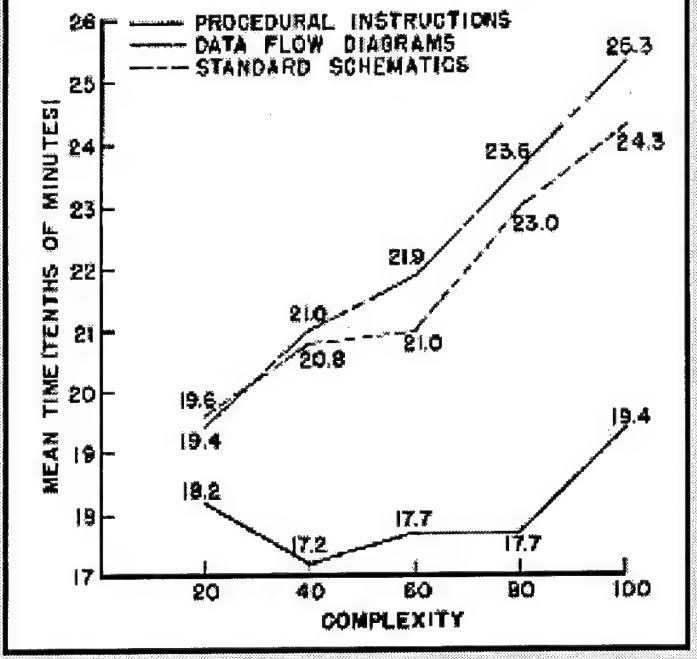


DETERMINING THE CENTER OF GRAVITY OF AN AIR CREWMAN

One of 118 subjects restrained in a pendulum apparatus to determine the center of gravity and moment of inertia of a sample of U.S. Air Force air crewmen. Subjects were selected to be representative in stature and weight of the Air Force population. The work was done under Task 718408, "Anthropology for Design" by J. DuBois, W.R. Santschi, D.M. Walton, C.O. Scott, and F.W. Mazy of North American Aviation, Inc. AMRL-TR-64-110 (1964)



PRESENTATION TECHNIQUES FOR FAULT ISOLATION

Time to isolate equipment faults for three presentation techniques and five levels of complexity. AMRL-TR-64-57 (1964)

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"I was lucky enough to be on the selection committee for the original seven Project Mercury astronauts. I had done the anthropometry on all of the candidates, as well as stereo photographs. The photos were to be used to provide accurate body shape information, which would then enable us to make customized pressure suits . . . It was an interesting time in the lab for a few weeks, having all the astronaut candidates around taking tests, meeting, and discussing the results. All the candidates were very impressive, but John Glenn was in the 99th percentile on everything. He was amazing."

— Charles Clauser, Anthropologist Human Engineering Division

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By the 1950s, progress had been made at the lab that expanded work to include space research. Human engineering scientists studied the effects of weightlessness as well as the psychological problems peculiar to the spacecraft. They developed techniques to protect and enhance man's performance on supersonic rocket flights in new, high-altitude environments. Astronauts practiced working with new space tools during weightlessness missions while wearing bulky space suits and 160-pound backpacks which propelled them through space. They also learned how to assemble a space station and how to repair and retrieve satellites while in orbit.

— May 1985, "Human Engineering, Yesterday and Today," Civilian Employees Reporter

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"I was in the original Applications Branch, along with Charlie Bates, Dave Greek, and Austin Kibler. We were involved with the preparation of MIL-H-26-207, which was the first human factors data for guided missile systems. We drafted and finally got acceptance from the Air Force for that first human factors specification. The new spec could then be incorporated in the system development programs, which legitimized a lot of the human factors people who were in the aerospace industry at that time. It forced management to have human factors people in the loop in the design approval process. Human factors personnel had sign-off responsibility on all top-line drawings during the design process. This was a real "first;" it had considerable impact on the field."

— Donald Topmiller, Chief Systems Research Branch Human Engineering Division

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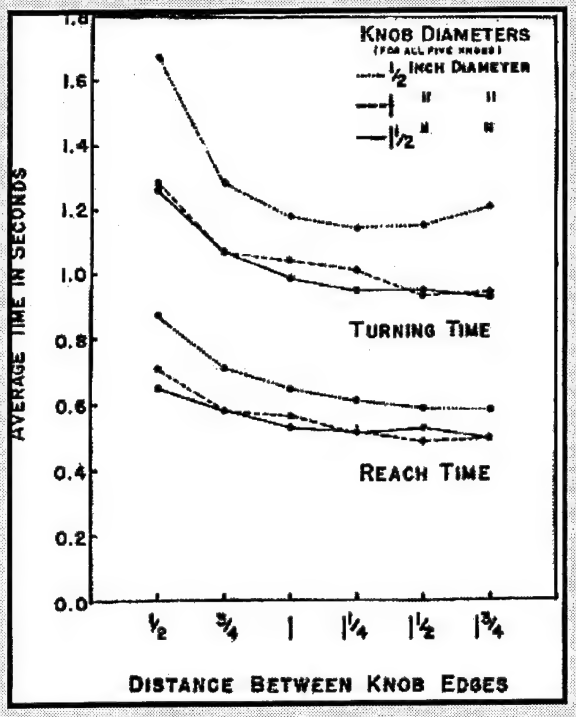

EFFECTS ON PERFORMANCE OF KNOB SIZE AND SPACING

Turning and reach times for knobs of different sizes as functions of distance between knob edges. From a study of minimum allowable knob crowding carried out by James Bradley and Norman E. Stump under Research and Development Task No. 71514 on control design and arrangement. WADC-TR-55-455 (1955)

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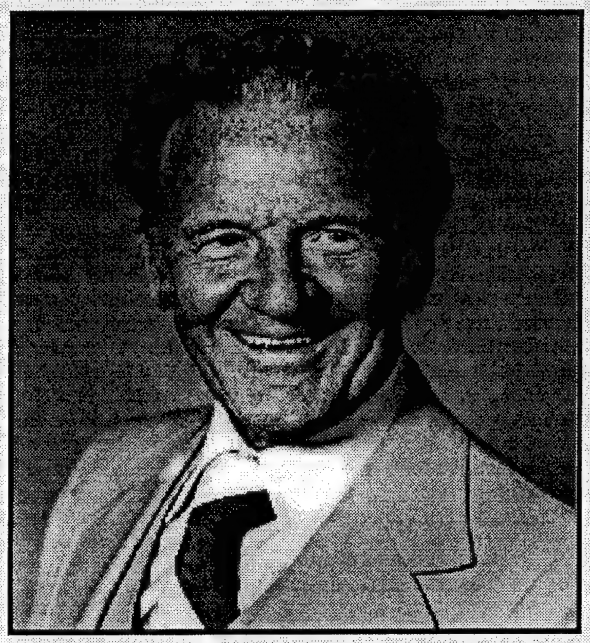
Julien M. Christensen, PhD
Chief, Human Engineering Division

1956 to 1974



Julien M. Christensen was assigned as a first lieutenant, US Army Air Force, to the Psychology Branch, Aero Medical Laboratory in October 1945. When he separated from military service as a captain in 1946, he was hired immediately by Lt Col (Dr.) Paul Fitts, Chief of the Psychology Branch. Prior to that time, Chris had been a personnel technician in the Trade Test Division of the US Army's Adjutant General's Office (1941) and in the US Army Air Force's Aviation Psychology program conducting research on navigator selection. He went through Navigator Cadet training and later radar/bombardier training and was assigned to the Army's Aviation Psychology program doing research on navigator training.

He became Chief of the (renamed) Human Engineering Division in 1956, a position he held until retirement from civil service in 1974. Chris supervised an interdisciplinary team of over 60 engineers, scientists, and technicians in human factors research and development programs for the United States Air Force. These programs included visual perception, displays, controls, control dynamics, environmental factors, performance modeling, maintainability, human reliability, information processing, decision making, safety, and physical anthropology. He was particularly honored by being elected to the International Explorers and Pole Vaulters Club, being the first civilian scientist to fly with the Air Force over the North Pole (1947). He chaired the Human Performance Advisory Committee, Manned Orbiting Laboratory, and contributed heavily to various bioastronautical and other long-term programs. He was twice (1964-65 and 1986-87) President of the international Human Factors and Ergonomics Society and was awarded an honorary Doctor of Science degree (1989) by the University of Dayton. Subsequent to his retirement from civil service, he became Chairman (1974-1978) of the Department of Industrial Engineering, Wayne State University. Following that, he became Chief Scientist, General Physics Corporation from 1980 to 1984 and later a consultant and Senior Human Factors Scientist at Universal Energy Systems in Dayton, Ohio.

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A SUBJECT USING BIMODAL CONTROLS TO OBTAIN DATA FOR DESIGN CRITERIA

A subject being tested on simultaneous activation of bimodal controls in a study done under Project 7184, "Human Performance in Advanced Systems," Task 718404, Advanced Systems Human Engineering Design Criteria. The work was performed by Melvin J. Warrick and Lester Turner. AMRL TDR-63-6 (1963)

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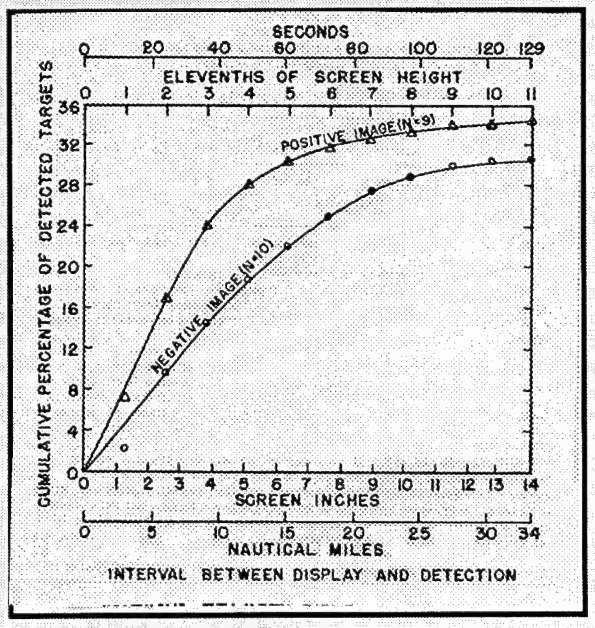

TARGET DETECTION AS A FUNCTION OF IMAGE POLARITY

Data comparing detection of targets with positive and negative image polarity on a side-looking radar display. The work was performed jointly under Program 665A, "Precision Strike," and Task 718404, "Advanced Systems Human Engineering Design Criteria." The work was performed by Barbara A. Van Ausdall and Dr. Herschel C. Self. AMRL-TR-64-82 (1964)

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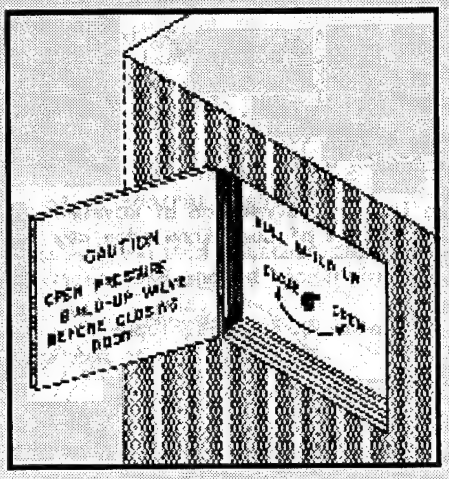

DESIGNING FOR MAINTAINABILITY

An example of labeling instructions for hazardous tasks; taken from a guide for designing mechanical equipment for maintainability. This work examined design factors for accesses, connectors, fasteners, labels, instructions, etc. and made recommendations for maintenance of support equipment. The work was done under Task 71586, "Design for Maintainability," by James W. Altman, Angeline C. Marchese, and Barbara W. Marchiando of the American Institute for Research. ASD TR-61-381 (AD 269 332)(1961)

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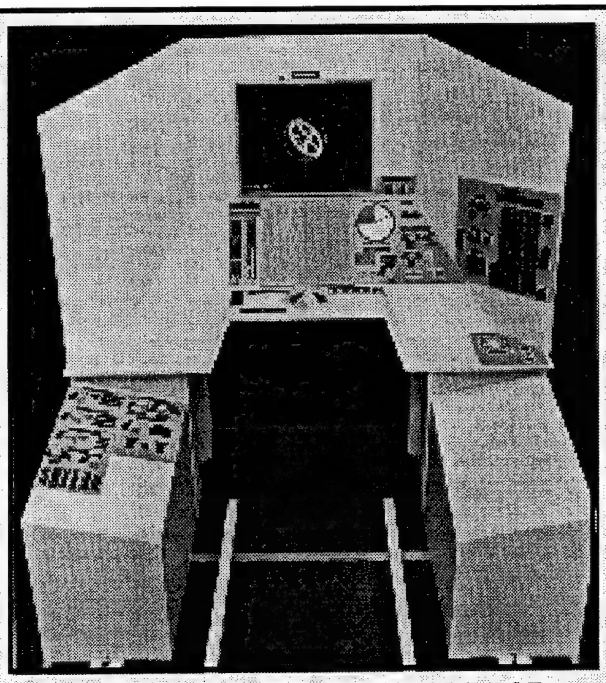
TESTING AN EARLY MODEL OF AN EXTRA-VEHICULAR PROPULSION UNIT

Sgt Bill Sears in a C-131B aircraft wearing a jet-propelled, manual-control extra-vehicular propulsion unit called a locomotion belt while assessing a human's ability to rotate his body in a zero-gravity environment. After considerable experimentation and design effort, these propulsion units were developed into the equipment used by the American astronauts for extra-vehicular excursions. The aircraft was flying in a parabolic flight path or orbit to produce the free-fall condition of zero gravity such as occurs in an earth-orbiting space vehicle. This picture was taken during an experiment in 1961.



DISPLAYS AND CONTROLS FOR MANNED SPACE FLIGHT

Cockpit mockup used in a study of display and control requirements for manned space flight. This work was done under Project No. 7184, "Human Performance in Advanced Systems," and Project No. 7185, "Design Criteria for Crew Stations in Advanced Systems." The work was done by Charles O. Hopkins, Donald K. Bauerschmidt and M.J. Anderson of the Hughes Aircraft Company. WADD-TR-60-197 (1960)

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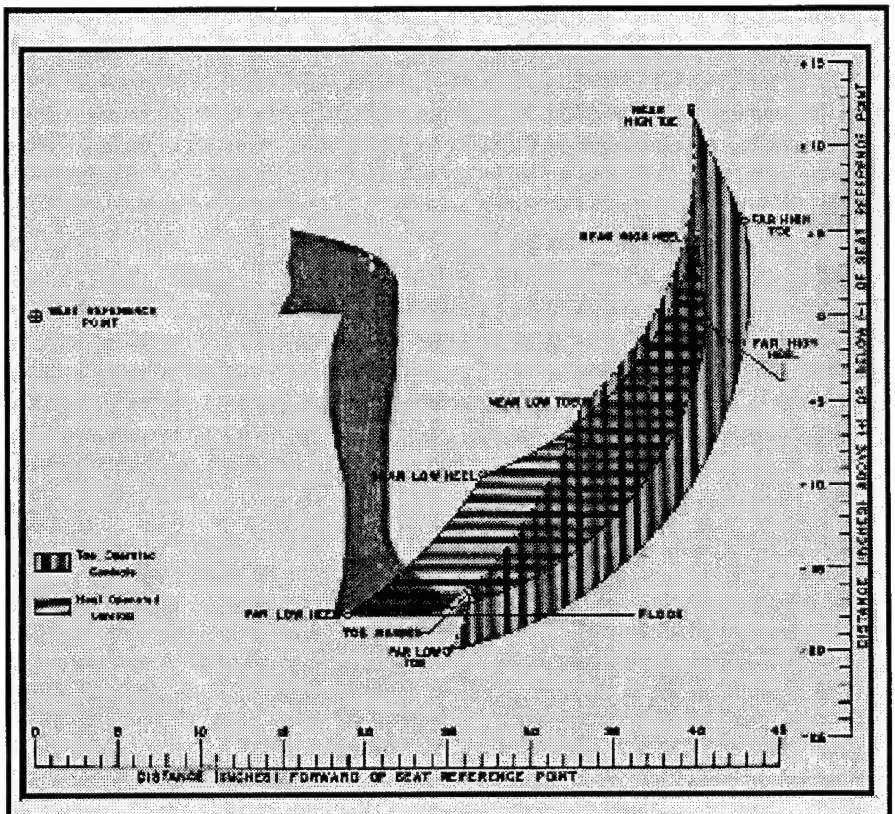

ANTHROPOMETRY OF WORKPLACE LAYOUT

A chart for foot-pedal activation by a seated operator. The chart is from a compilation of human engineering recommendations on various aspects of the layout of workplaces including general considerations, workplace dimensions, location of controls and displays, and direction of motion relationships. This report was prepared under Research and Development Project 7180, "Human Engineering Applications to Equipment Design" by Jerome H. Ely, Robert M. Thomson, and Jesse Orlansky. WADC-TR-56-171 (1956)

The Human Has Limitations

Engineering psychology began with the intellectual discovery that the human was not a perfectly adaptable organism. Of course, no one had ever formally asserted that the man was perfectly adaptable, but up until a few years ago the applied psychologist acted as if the human's flexibility were sufficient to make possible all important adjustments between man and his environment. We now know that this is not so. All of us are aware of how, during World War II, the approach of designing the task to fit the operator was added to the more traditional psychological procedures of selecting and training operators to fit their jobs. This was necessitated by the variety and complexity of military equipment. Machinery had finally outrun the man's ability to adapt. And the recognition of this fact was the first important insight in the development of engineering psychology.

— Franklin V. Taylor, 1960, "Four Basic Ideas in Engineering Psychology," The American Psychologist

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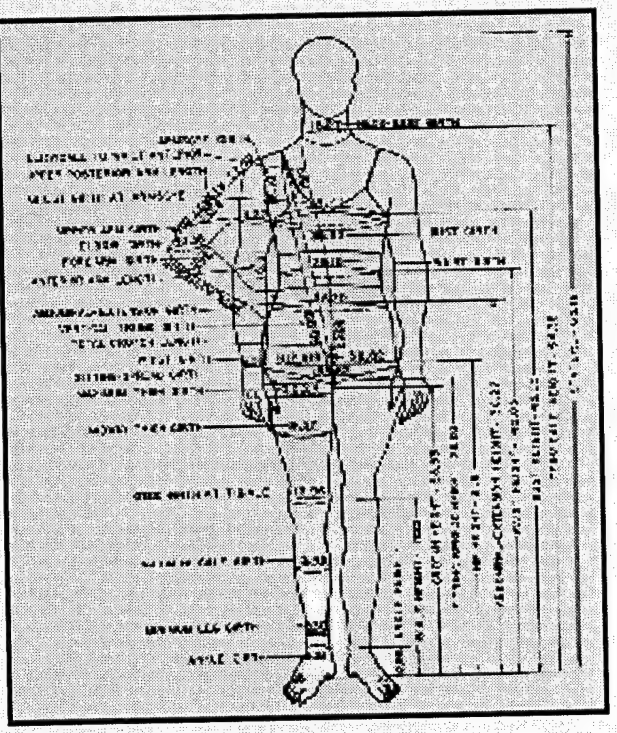

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VISUAL TRAINING PROCEDURES
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Most of the efforts of the Behavioral Sciences Laboratory are classified as applied research, i.e., research directed toward the solution of problems anticipated in future Air Force systems. Unless the research is aimed from 3 to 10 years into the future, it is likely to be too late by the time research is completed. Although identified as applied research, much of our research is planned so that it has general scientific value beyond the application to a particular Air Force problem.

— March 1965, "Human Engineering and Training Research Division," Behavioral Sciences Laboratory

As a student of Professor Fitts, I well remember his emphasis on rigor in research, on exhaustive inquiry, on plain hard work, his impatience with those who did not share his regard for these qualities, and his complete willingness to give unstintingly and unreservedly of his own ideas, assistance and time to any student who did. He was a firm but gentle and inspiring adviser.

— Julien Christensen, June 1965, "Paul M. Fitts Memorial Issue," Human Factors Society Bulletin

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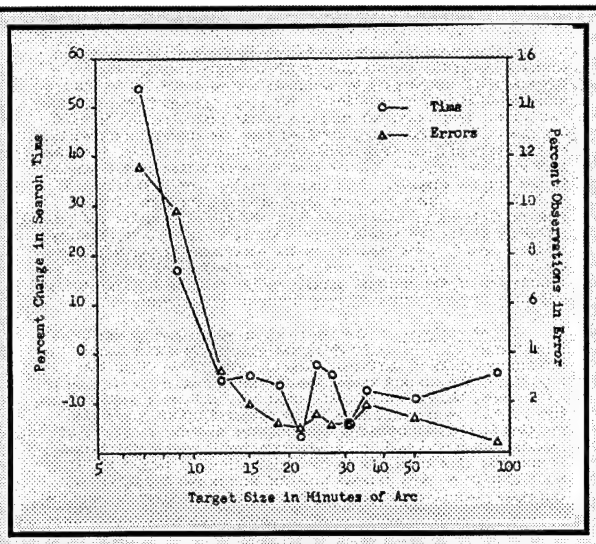

TARGET DETECTION AS A FUNCTION OF TARGET ANGULAR SIZE

A graph of search time and errors as functions of angular target size in minutes of arc. This work was done under Task 71580, "Criteria for the Design and Arrangement of Displays," by William C. Steedman and Charles A. Baker. WADD-TR-60-93 (1960)

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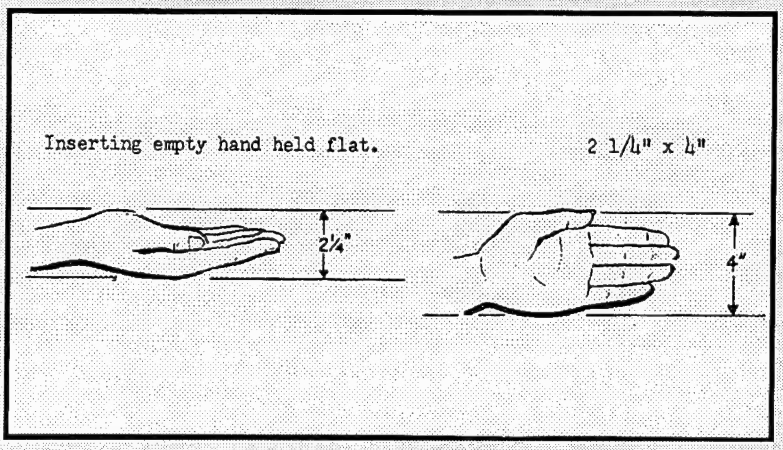

EXCERPT FROM A GUIDE FOR DESIGN AND MAINTAINABILITY

Required size of an access opening for one-hand tasks from a design guide for maintainability containing recommendations on design practices for maximizing the ease with which electronic equipment can be maintained. The work was done by John D. Folley, Jr. and James W. Altman of the American Institute for Research. WADC-TR-56-218 (1956)

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SELECTING INSTRUMENT SCALES FOR READING EFFICIENCY

Testing for reading efficiency with various scale shapes, exposure times, and response complexities. This work, a part of the research on man-machine systems of the Aviation Psychology Branch, was done by Edwin H. Elkin of The Ohio State University. WADC-TR-58-472 (1959)

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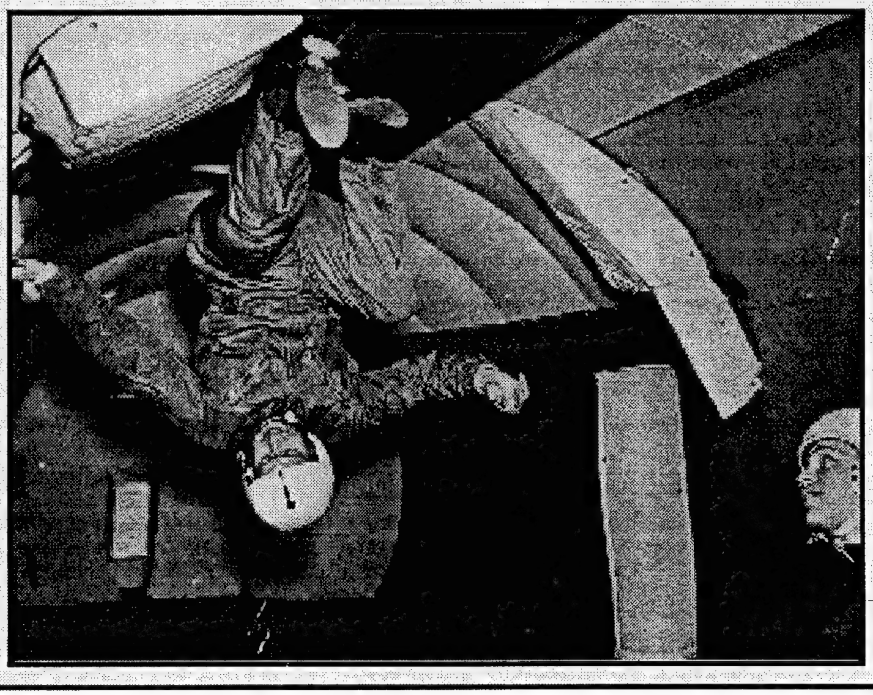
SUBJECTS IN ZERO GRAVITY IN AN AIRCRAFT

Test subjects floating in zero gravity in an aircraft in a flight path that produces zero gravity. These flights were designed to test the effects of weightlessness on the crew members of future vehicles in orbit around the earth. These tests, conducted by the Human Engineering Branch, were later continued and extended by NASA.



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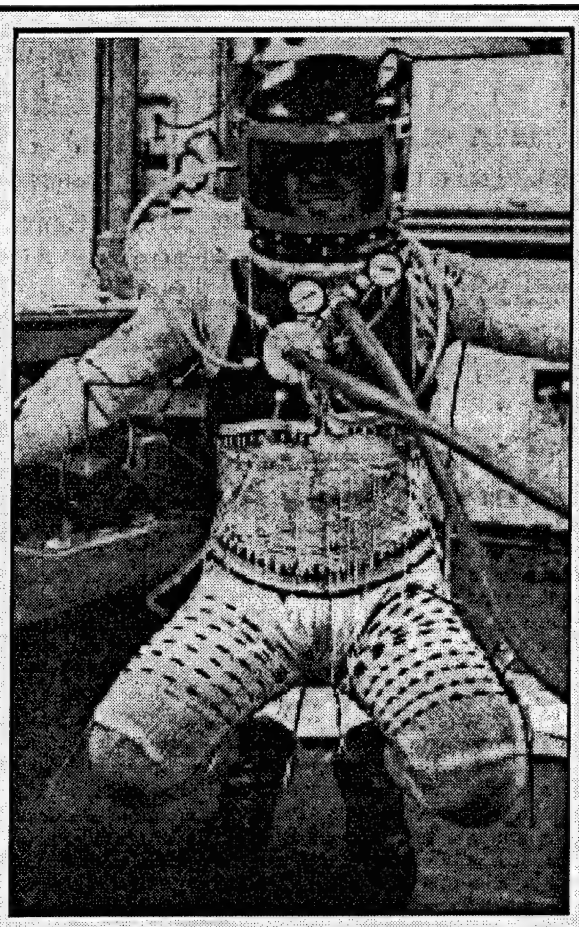

KNEE BENDS IN A PARTIAL PRESSURE SUIT

A subject performing deep knee bends in a full-pressure suit in a study to obtain data for designing pressure suits that could provide natural mobility and minimal ballooning. The work was done under Task 718408, "Anthropology for Design" by Author S. Iberall of the Rand Development Corporation. AMRL-TR-64-118 (1964)

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"The most important and satisfying work I was involved with was the development and implementation of the Human Engineering System Simulator. It was based on an IBM 360-40 and was the first system that allowed us to do multi-operator simulation research. At that time we had a requirement to do command and control studies involving systems like the AWACS. The facility was constantly threatened by the base Computer Center, who felt that a laboratory should not have such a large computer facility. I spent a lot of time convincing them that it was a research facility rather than a data processing facility. There was no other facility like it at that time. We did a lot of good research during those years."

— Don Topmiller, Chief Systems Engineering Branch Human Engineering Division

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"I got interested in the study of models used to estimate the total body moments of inertia and body part moments of inertia. We did not have computer models back then. I developed a wooden model that represented—at least mathematically—those parameters. That led to further development in the area of mass distribution characteristics of the human body. This information was important for predicting how the body would respond when in motion, or to changes in motion. NASA, of course, had a tremendous interest in this, so they funded a project I had proposed to expand and improve the data. We collected the measurements from cadavers, using the facilities at FAA Civil Aeromedical Institute in Oklahoma City—probably the best anatomy lab outside of the universities. Measurements of volume, mass, and center of mass for various body parts were collected. We then prepared regression equations from the data. A lot of those equations are still being used today."

— Charles Clauser, Anthropologist
Human Engineering Division

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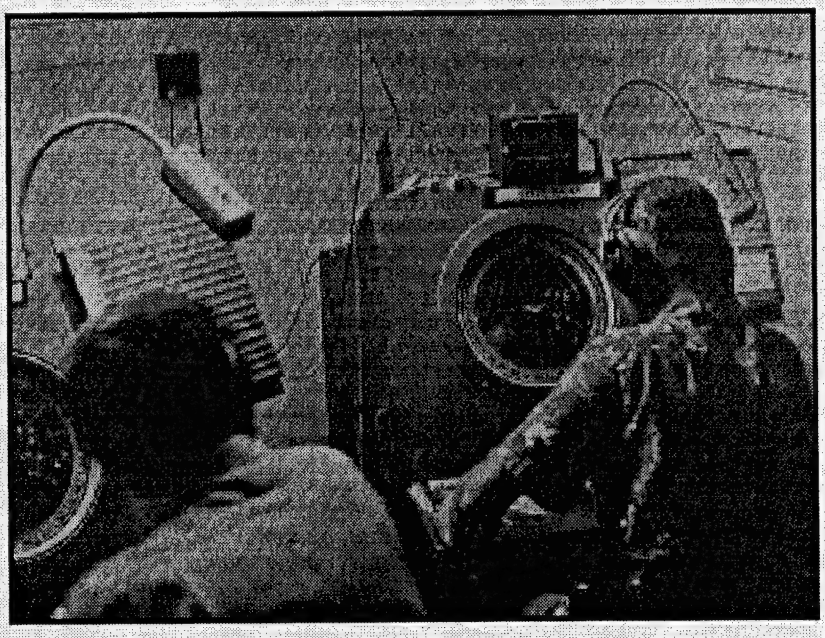

BROAD-BAND BLUE LIGHTING FOR CONTROL ROOMS

Evaluating a broad-band blue lighting system for radar approach control centers (RAPCON) to assist in developing such a system as part of the research on human engineering problems of air traffic control. This work was carried out by Conrad L. Kraft of The Ohio State University. WADC-TR-56-71 (1956)

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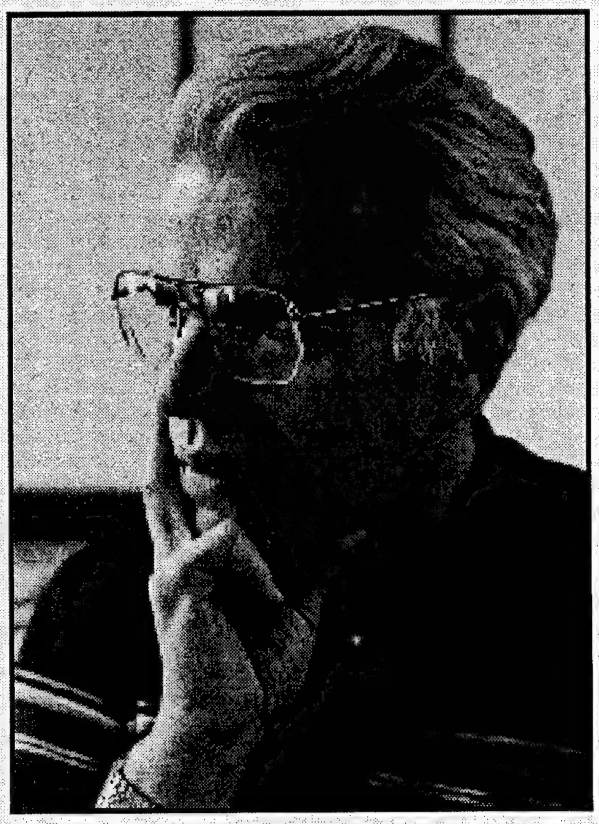
Seeger, C. M. (1955). *Suitability of the MA-1 signal generator - auditory warning signal for use in USAF Aircraft Headsets* (WCRD Technical Memorandum Report 55-37). Wright-Patterson AFB, OH: Wright Air Development Center.

Colonel John C. Simons

Researcher
Human Engineering Division

1956 to 1966
1968 to 1971



John Simons was one of the most prolific and creative minds ever assigned to the Human Engineering Division of the Aero Medical Laboratory (now Armstrong Laboratory).

His contributions span four decades as a soldier, scientist, engineer and leader. Early on, Capt Simons was an important contributor to the Aero Medical Laboratory's partial role in the Mercury Space Program. He was one of the principals responsible for development of the parabolic flight trajectory used to simulate "zero-G" for engineering and astronaut training. Zero-G testing included such things as hydraulics, space locomotion, and human and animal physiological response. Variations of the parabolic flight profile are still used today by NASA in their C-135 zero-G aircraft.

Another notable achievement by Capt Simons was the development of the Long Lines personnel extraction system. It had long been understood that an aircraft flying a coordinated "pylon" turn could lower a cable which at the pylon turn point would hang stationary. This quirk of physics was exploited to recover personnel from behind enemy lines. The Long Lines system was tested with both mannequins and human volunteers and was operationally deployed. Although later supplanted by the Fulton extraction system, the Long Lines system pioneered the concept of rescue by fixed-wing aircraft.

As a major, Simons flew combat in his third war, Vietnam, with the famous 1st Air Commando Unit. Wounded in combat, he convinced the doctors to let him convalesce in Dayton. His first day back in the country, he appeared on crutches in the laboratory and eagerly passed his new combat experience to his fellow scientists and engineers.

The most important idea to emerge was the lateral firing gun. Again employing the pylon turn, lateral firing ordnance could be aimed with extraordinary accuracy. Upon his reassignment to the laboratory as a branch chief, Simons doggedly pursued the idea and eventually wangled a briefing to the Chief of Staff, then General Curtis LeMay. Gen LeMay was convinced and ordered that the prototype for what would become the AC-47 be built and tested at the Eglin AFB range. The tests were so successful that the aircraft was flown directly to Vietnam and immediately deployed in combat. John Simons is credited as co-inventor of the "gunship" which has served so successfully in Vietnam, Grenada, Panama, Iraq and Somalia.

John Simons continued to make creative contributions to the Human Engineering Division as a contractor after his retirement. His last contribution, one of the original 1968 combat-born ideas, was the Sensor Platform Imagery (SPI). SPI is a real-time reconnaissance drone which allows strike air crews to review the target minutes before they attack. A laboratory simulation completed in 1993 confirmed the effectiveness of SPI more than 20 years after the original Simons idea.

The creative genius of John Simons is a tribute to the soldier-scientist. The unique combination of master's degree, flying knowledge, combat experience, and a dedicated Air Force laboratory environment turned his creativity into exceptional productivity.

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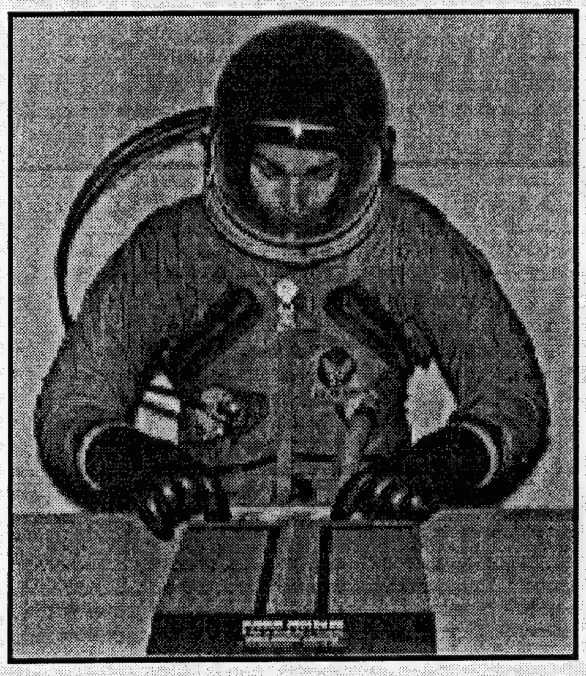

TESTING FINGER DEXTERITY WHILE WEARING A PRESSURE SUIT

A pressure-suited subject being tested with the Purdue Pegboard Dexterity Test for finger dexterity in a study to establish an objective baseline for evaluating the functional mobility of pressure gloves. This study was done under Task 718408, Anthropometry for Design by Dieter E. Walk. AMRL-TR-64-41 (1964)

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Senders, J. W., & Bradley, J. V. (1956). *Effect of backlash on manual control of pitch of a simulated aircraft* (WADC Technical Report 56-107). Wright-Patterson AFB, OH: Wright Air Development Center. (DTIC No. 95 404)

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ASTRONAUTS, AIRCREW MEMBERS, AND EXPERIMENTERS

Participation in zero gravity flights conducted to determine effects on humans and their performance in space.

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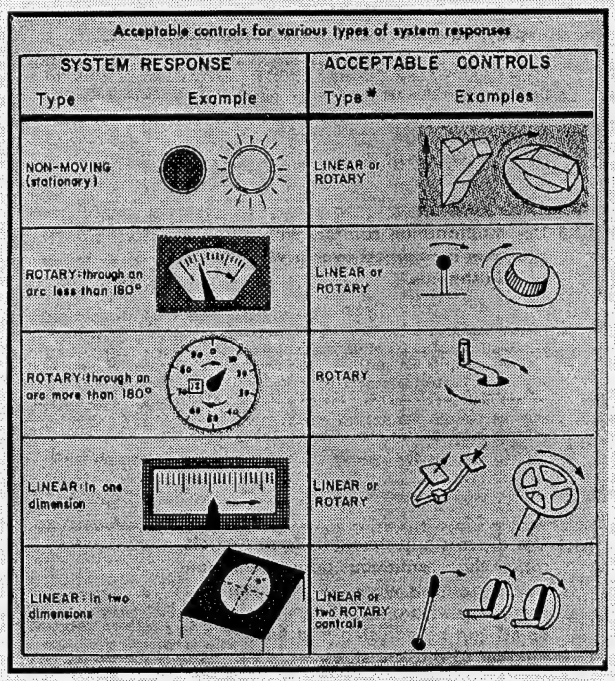

THE DESIGN OF ACCEPTABLE CONTROLS

A figure illustrating acceptable controls for several types of system responses from research done under R&D Project Number 7180, "Applications to Equipment Design." The document gave general rules for selecting controls, discussed control characteristics, and gave considerable attention to detailed design recommendations. The work was done by Jerome H. Ely, Robert M. Thomson and Jesse Orlansky of Dunlap and Associates, Inc. WADC Technical Report 56-172 (1956)

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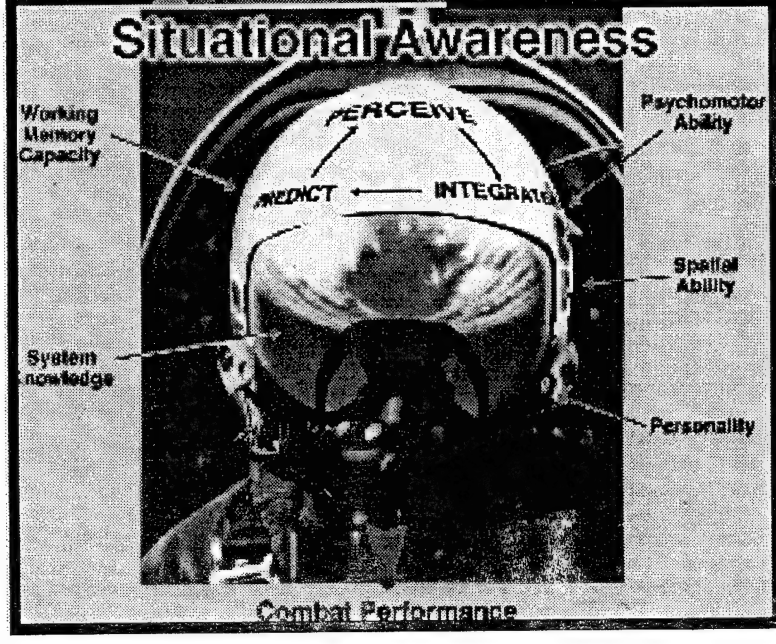
The Vietnam War Years

1965-1974

A seemingly small war in a far-off land will teach the nation painful lessons about fighting limited wars with limited military objectives and limited success. As in all wartime eras, pressure on the military and its laboratories to expedite better weapons to the battlefield is intense. A famous laterally firing gun-ship concept is co-founded in the Human Engineering Division and used effectively in Vietnam. The strong scientific and technical leadership of Drs. Christensen and Warrick continues.



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DESIGN DATA FOR FEMALE CLOTHING

Measuring the biceps of the flexed left arm of a female Air Force member during data collection for an anthropometric survey. The data were used in the design, sizing, and procurement of clothing and the intelligent design of equipment and layout of functional workspaces for women in the military. This work was done by Charles E. Clauser and Lt Col Pearl E. Tucker of AMRL and John T. McConville, E. Churchill, Lloyd L. Laubach and J.A. Reardon of Webb Associates, Inc. AMRL-TR-70-5 (1972).

By the mid 1960s . . . NASA had taken over the manned space program, and the lab concentrated its efforts on weapon systems used in the Vietnam War. They developed side-firing gunships that became one of the most effective weapons of that war.

— May 1985, "Human Engineering, Yesterday and Today," Civilian Employees Reporter

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VILLAGE USED IN AN AIRBORNE STUDY OF THE EFFECT OF OBSERVER FIELD OF VIEW

A simulated Viet Cong village used in an airborne study of visual reconnaissance with two fields of view. This study was in support of Advanced Development Program 665A, "Reconnaissance Strike," and Task 718404, "Advanced Systems Human Engineering Design Criteria." The work was done by Charles Bates, Jr., Steve A. Heckart, Herschel C. Self, D.F. McKechnie, and E.P. Hanavan. AMRL-TR-68-43 (1968)

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MEASURING ARM REACH CAPABILITY
A subject in a test apparatus for measuring the arm reach capability of lightly clothed and pressure-suited air crewmen. The data attained were used for the placement of aircraft controls. The work was done under Workunit 71840808, "Layout of Workplaces" by John W. Garrett, Milton Alexander, and Chester W. Matthews. AMRL-TR-70-33 (1970)

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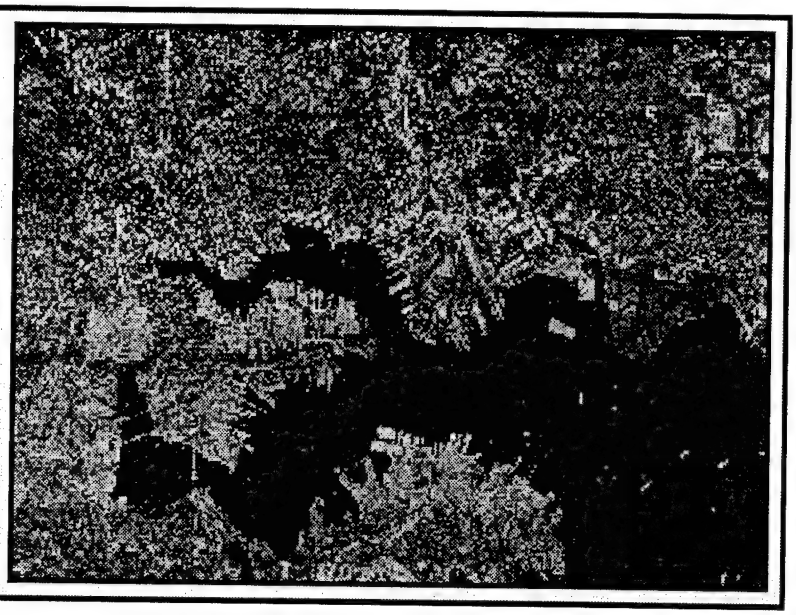
TESTING DETECTION OF BRIEFED TARGETS AS A FUNCTION OF AIRCRAFT SPEED

Example of some of the side-looking radar imagery used in a study on the effects of prior target briefing on identifying targets on a display from aircraft moving with different simulated velocities. The work was performed jointly under Program 665A, "Reconnaissance/Strike Systems," and Task 718404, "Advanced Systems Human Engineering Design Criteria" by Don F. McKechnie. AMRL-TR-66-149 (1967)



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H.T.E. Hertzberg

Chief
Anthropometry Section and Branch

1961 to 1972

H. T. E. Hertzberg was assigned to the Aero Medical Laboratory in 1946 and later moved to the Human Engineering Division in 1961. He was the prime impetus for stimulating the military services to acknowledge the important need for definition of the human body size (anthropometric) variability of our military populations. His influence spanned the globe. The research facility, the Universite Rene Descartes in Paris, named its anthropometry laboratory in his honor. His anthropometric survey of 4000 flying personnel in 1950 became the "standard" for large-scale surveying, not only in the United States but internationally as well. Perhaps his greatest contribution was the anthropometric survey of NATO countries in 1960-61. This survey required incredible planning, organizing, and coordinating. Subjects were measured in three countries by a team with representatives from two services and three universities. The team, with Mr. Hertzberg in the lead, was in the field collecting data for a year.

As chief of the Anthropometry Section and then the Anthropometry Branch, he led his team in some of the most forward looking research of his time, including the first investigations of stereophotography as an anthropometric tool, the first developments of form-fitting liners for helmets, and the classic studies of dynamics and kinematics used in human body modeling. His work improved the fit, safety, and performance of all types of equipment systems including aircraft seats, oxygen masks, flight/space suits, high-altitude gloves, and automobiles. Many technological changes occurring since the Hertzberg era had their beginnings in his original research.

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"I got my start in the applications area of human engineering. It always impressed me that there were these guys out in the field using poorly-designed equipment—from a human engineering point of view. I felt our mission was to do something about this situation; I always thought we should have equipment designed so that at least its basic operation would be intuitively obvious . . . The one effort that I got great satisfaction out of — and that had the most benefit to the taxpayer and the flying Air Force—was the specifications and standards program. The problem is that, given the choice, most contractors will not spend the time and energy to design for the human operator, unless they have some incentive. Putting the specification and standard on the contract gives them incentive that gets them to do it. There was a lot of frustration and aggravation involved, but I still feel that this work was the most meaningful of all I have done while with the division."

— Steve Heckart
Applications Human Engineer
Human Engineering Division

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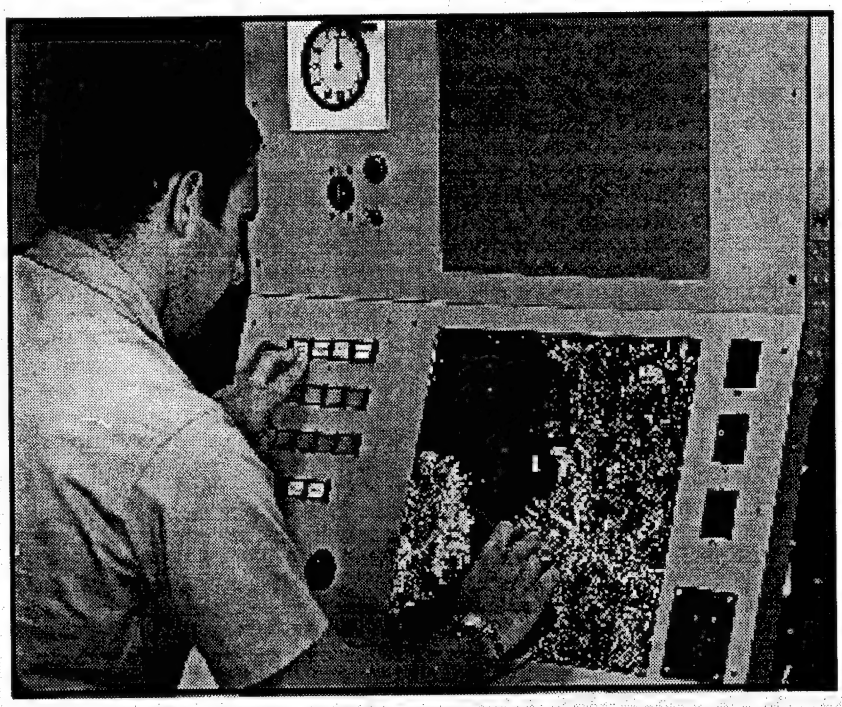
TARGET DETECTION COMPARED WITH DIFFERENT SENSORS

Military targets in a study comparing laser line-scan images with strip photography for ease of finding tactical targets. The work was performed under Project 7184, "Human Performance in Advanced Systems," Task 718404, "Advanced Systems Human Engineering Design Criteria" in support of the Reconnaissance Division of the USAF Avionics Laboratory, by Herschel C. Self and William S. Myers. AMRL-TR-69-115 (1970)

TESTING TARGET DETECTION WITH SIDE-LOOKING RADAR

Measuring the effects of the number of allowed target choices on the target detection behavior of observers using a moving-image display from a side-looking radar sensor. The man at the console is Dean Kocian. The work was performed jointly under Advanced Development Program 665A "Reconnaissance/Strike" and Task 718404, "Human Engineering Design Criteria for Reconnaissance and Reconnaissance/Strike Systems." The research was conducted by Herschel C. Self and Almon J. Bate. AMRL-TR-69-96 (1969)



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A HELMET-MOUNTED DISPLAY USED IN OPTIMIZING HELMET COUPLING

One of the helmet-mounted displays used in a program to develop an optimized optical link for a helmet-coupled system. The work was done by Mr. Eric R. Fehr of the Hughes Aircraft Company. AMRL-TR 73-20 (1973)

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"The person at the lab who had probably the greatest influence on my career was my first section chief, Ed Hertzberg. He was meticulous; he constantly tried to get us to write with some clarity of thought. He did his utmost to see that the job was done right. He was very, very thorough. I admired him for that . . . Another person was Mel Warrick. He was the acting chief when I came on board. He was a great person to talk to and a fantastic editor. I always felt we were so lucky to have him."

— Charles Clauser, Anthropologist Human Engineering Division

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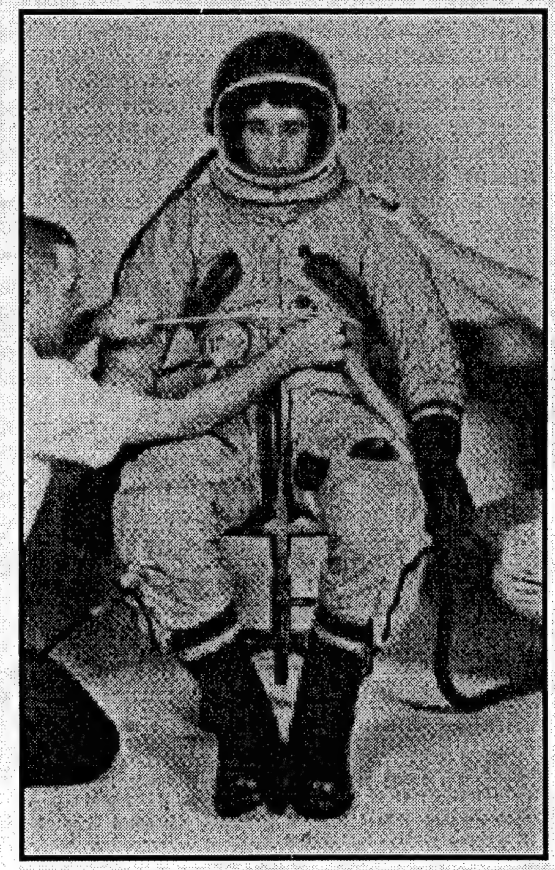

ONE OF MANY MEASUREMENTS ON PRESSURE-SUITED SUBJECTS TO OBTAIN DESIGN DATA

Milton Alexander measuring the mid-torso circumference of a seated subject wearing a pressure suit inflated to a pressure of 3.7 pounds per square inch. In this study, 138 measurements for standing, sitting, and supine positions were taken on each subject to formulate criteria for the design of workplaces. The work was done under Workunit 71840808 by Milton Alexander and John W. Garrett of the Human Engineering Division and Sgt Michael P. Flannery of the Air Defense Command. AMRL-TR-69-6 (AD 697 022)(1969)

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ORGANIZATION*

(As of 1965)

AIR FORCE SYSTEMS COMMAND

AEROSPACE MEDICAL DIVISION

6570th AEROSPACE MEDICAL RESEARCH LABORATORIES

BEHAVIORAL SCIENCES LABORATORY

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* From "Human Engineering and Training Research Divisions, March 1965," Behavioral Sciences History

Harshbarger, J. H. (1965). *Test and evaluation of electronic image generation and projection devices, Volume I. Evaluation techniques* (AMRL Technical Report 65-116(I)). Wright-Patterson AFB, OH: Aerospace Medical Research Laboratory. (DTIC No. 623 908)

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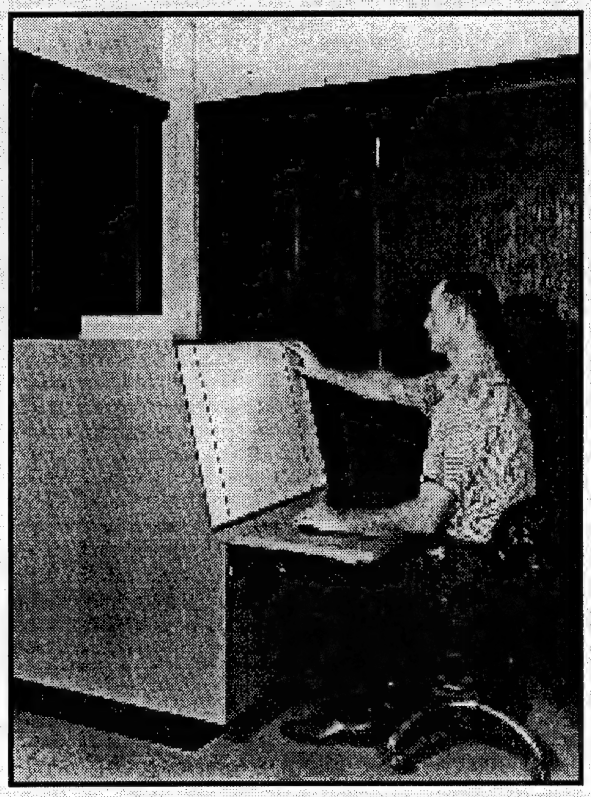

OBTAINING DATA FOR GROUND SUPPORT CONSOLE DESIGN

A user being tested during research intended to develop design standards for missile ground support consoles. The work was done under Project 7184, "Human Performance in Advanced Systems," Task 718404, "Human Engineering Design Criteria," and Task 718408, "Anthropometry for Design." The work was conducted by K.W. Kennedy and Charles Bates, Jr. AMRL-TR-65-163 (1965)

Hilgendorf, R. L. (1969). *Arousal level theory and aerospace medical research* (AMRL Technical Report 69-27). Wright-Patterson AFB, OH: Aerospace Medical Research Laboratory.

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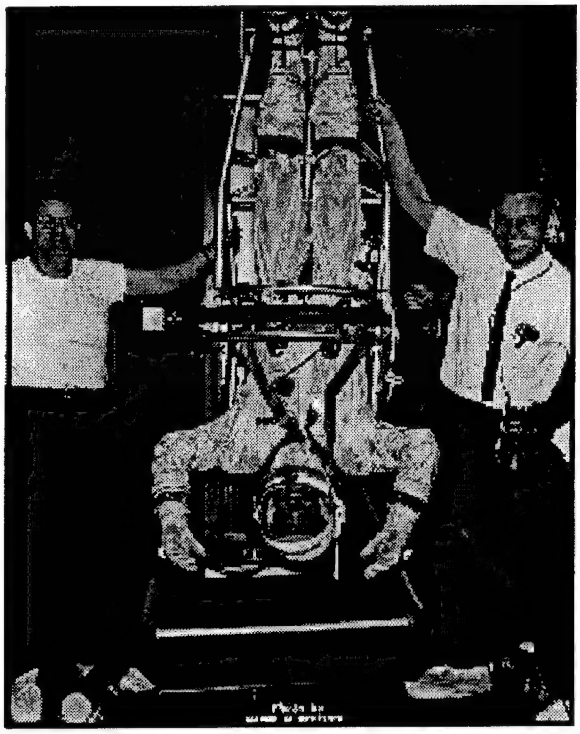
"My first assignment in the Human Engineering Division (August 1967) was to Don Topmiller's Systems Effectiveness Branch. Don was trying to establish a maintainability research program; and I, having had several years of aircraft maintenance experience, was most enthused about the prospects of solving some of the problems I had encountered throughout the years. The first opportunity for research came with a request from the Aero Propulsion Laboratory at WPAFB to evaluate quick-release panel fasteners for space applications. A zero-gravity simulation facility had already been completed in Building 21 in Area B (see figures at right and below); the facility provided a gimbaled support cradle, in which a person could be securely harnessed, riding on air-bearing pads over a poured epoxy floor, while tethered to a vertical work surface. With air applied, the air bearing pads rode approximately 0.002 inches above the epoxy floor, which was level to within 0.0005 inches over a 26-by-30 foot area. Work effort was measured in terms of forces and torques applied to the work panel (measured by strain gauges) as panels having various types of hand-operated fasteners were removed and installed. The data indicated that there were significant variances across the eleven very differently designed and operated fasteners, as well as interactions between fastener design and gravity conditions. The effort was documented in the Proceedings of the Second National Conference on Space Maintenance and Extravehicular Activities, Las Vegas, Nevada, August 1968. (AMRL TR-68-117)

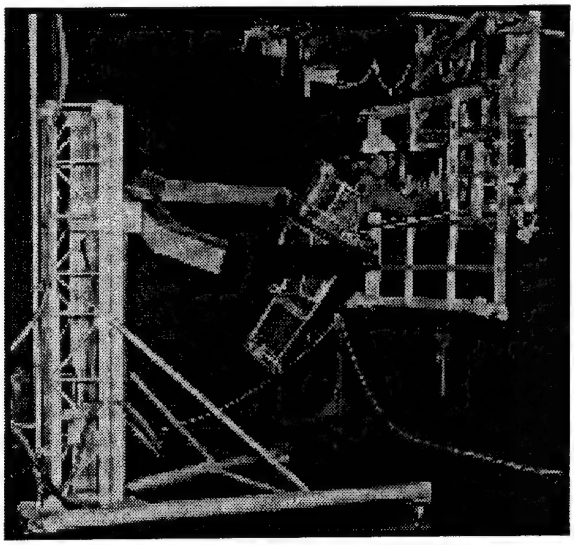
We were about to explore the effect of deflated and inflated space suit encumbrances upon performance requirements for operation of some of the better fastener designs when we were directed to stop related research in deference to NASA."

— Wayne L. Martin
Chief, Visual Display Systems Branch
Human Engineering Division



JULIEN M. CHRISTENSEN INVERTED IN ZERO-GRAVITY SIMULATION FACILITY

This device, riding on air bearing pads on a poured epoxy floor that was level to within 0.0005 inches over its 26 by 30 foot area, was used in the evaluation of forces and torques required for panel fastener operation under simulated zero-gravity conditions. Bernie DeWinter, one of several instrumentation technicians provided by the Aero Propulsion Laboratory, is on the left. Wayne L. Martin is on the right. (1968)



MEASURING FORCES AND TORQUES WHILE IN A ZERO-GRAVITY SIMULATOR

Work in conjunction with the Aero Propulsion Laboratory to determine human performance requirements for hand-operated fasteners for space applications. The support cradle, coupled with air bearings on the poured epoxy floor provided tethered movement with six degrees of freedom under near-frictionless conditions. Forces and torques required to remove and install fasteners under normal gravity and simulated zero gravity, as measured by strain gauges on the work panel, identified significant differences across fastener design and interactions between fastener design and gravity conditions. The research was done by Wayne L. Martin, Billy M. Crawford, William N. Kama and J. Herman. AMRL-TR-68-117 (1968)

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During the 1960s . . . (members of the Human Engineering Division) were also busy making modifications for B-52 crew stations which, in turn, led to the development of new simulation techniques. Man-in-the-loop simulation put a person in a certain job scenario while he was still on the ground. This helped reduce the need for flight tests, and helped researchers measure the performance of both the person and the equipment. This system continues to be used in the Air Force. Future plans call for a similar program to be used with future strategic crew systems.

— May 1985, "Human Engineering, Yesterday and Today," Civilian Employees Reporter

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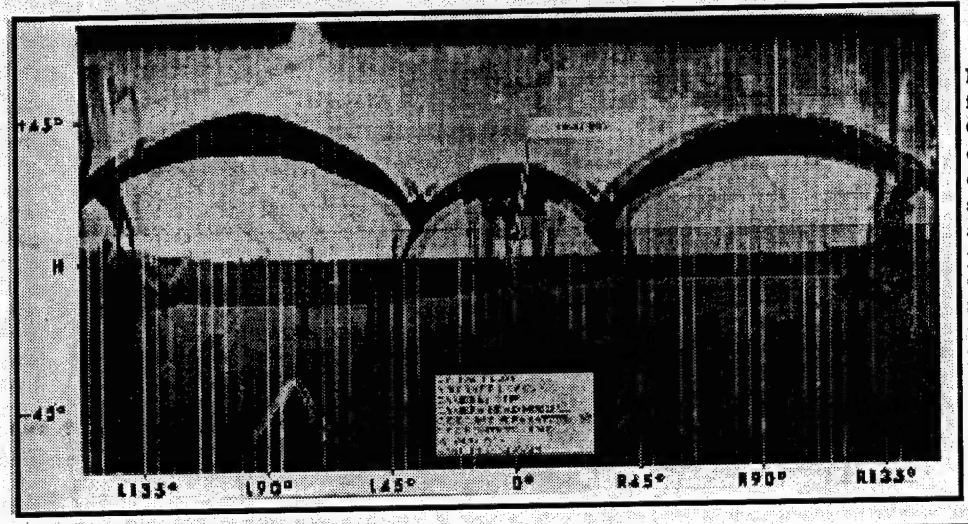

VISIBILITY FROM THE COCKPIT

Binocular ground visibility from the cockpit of a level OV-10A-111 aircraft; extracted from a compilation of visibility measurements on several types of military aircraft. The work was performed under Program 665A, "Reconnaissance/ Strike Subsystems" and Tasks 718404, "Advanced Systems Human Engineering Design Criteria," and 718408, "Anthropology for Design" by Kenneth W. Kennedy and Don McKechnie. AMRL-TR-69-123 (1970)

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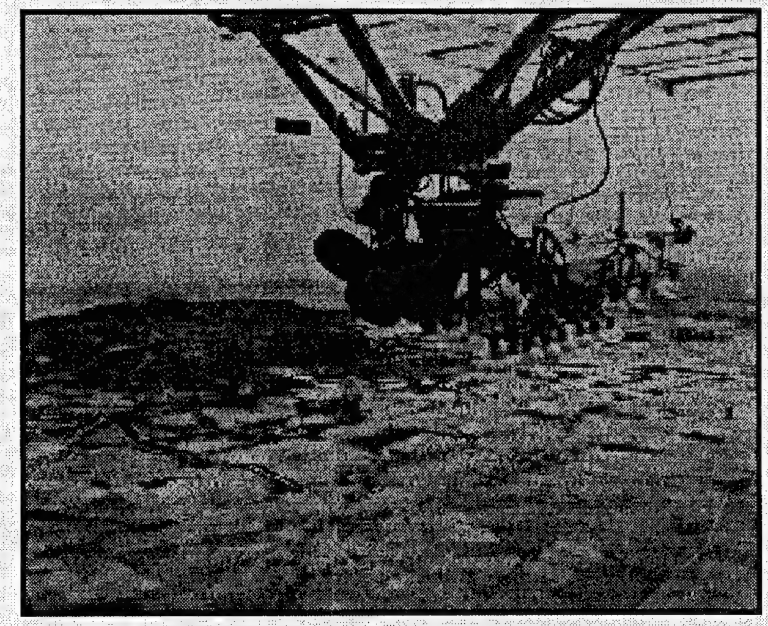
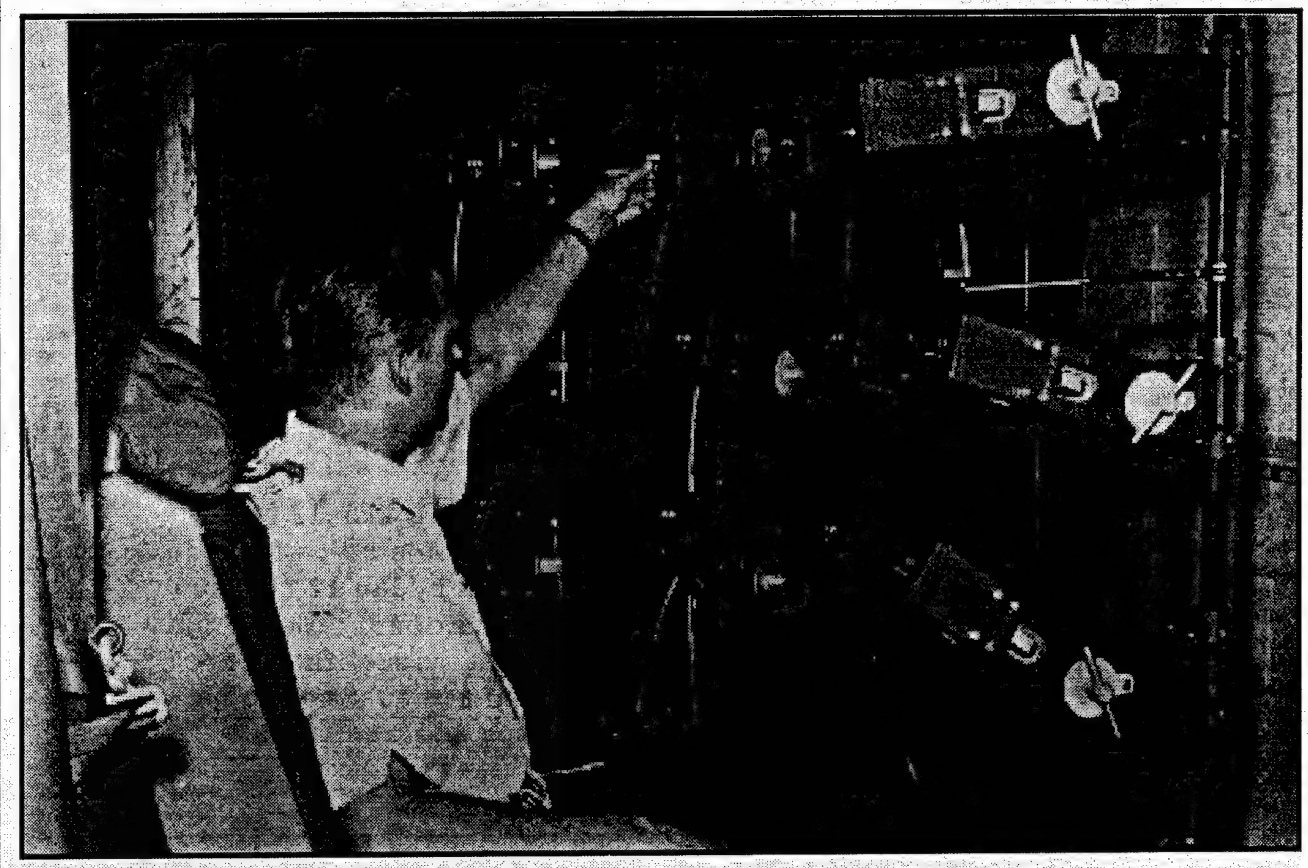


SETUP FOR MEASURING THE EFFECTS OF SYSTEM CHARACTERISTICS ON TARGET RECOGNITION

Terrain model and gantry-mounted, closed-circuit TV camera used to simulate aircraft flight at low-light levels. The system features a TV viewfinder for measuring the effects on target recognition of system characteristics. The work was done on contract to North American Rockwell Corporation in support of the Directorate of Reconnaissance Engineering and sponsored by the 665A Program Office. The work was done by J.M. Humes and D.K. Bauerschmidt. AFAL-TR-68-271 (1968)



TESTING THE EFFECT OF PANEL LAYOUT ON VISUAL FIXATION AND UNCERTAINTY

Testing in a workplace efficiency evaluator for the effects of panel layout on visual fixation and uncertainty. The work was conducted under Task 718402, "Criteria for the Design and Arrangement of Controls and Control Systems." The research was done by Donald A. Topmiller and Earl D. Sharp. AMRL TR-65-149 (1965)

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"I had been a machinist before I began to get interested in human factors; so, when it came time to start rebuilding and modifying the simulators to suit our needs, I was able to go to the base machine shop and tell the machinists exactly what we needed, in their language. This way I was able to get the facility set up extremely quickly."

— Earl Sharp, Program Engineer
Human Engineering Division

"My first task was the zero-G project. I replaced Bob Kellogg, who had been developing a machine which would spin the subject around the axis of the eyes in a zero-G environment, to study whether the tendency for the eyes to counter-rotate was a vestibular function or some kind of reflex. That's how I got into the program. After that, I did a lot of work in the areas of vestibular and visual functions as well as performance—all in zero-G."

— Robert O'Donnell, Chief
Workload and Ergonomics Branch
Human Engineering Division

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The Human Engineering Division includes most of the work areas of the original Psychology Branch, which ultimately grew into the Behavioral Sciences Laboratory. In this branch the primary concern is with research on human performance that could lead to improvements in the design of operating procedures for Air Force systems. The ultimate objective, of course, is to maximize the effectiveness of our weapon systems by properly matching human and machine capabilities and functions.

— March 1965, "Human Engineering and Training Research Division," Behavioral Sciences Laboratory

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Melvin J. Warrick, PhD

Associate Chief
Human Engineering Division

1958 to 1973

Mel Warrick was hired into the Psychology Branch, Aero Medical Laboratory, in March 1946 by Lt Col Paul Fitts, then its Chief. Prior to that time he had been in military service undergoing gunnery, bombardier, and radar operator/ navigator training and doing research on bombardier training in the Army Air Force's Psychology Program. Before that, Mel had been trained as a private pilot, had taught high school science and mathematics, and had done research from 1941 through 1943 on bombardier selection for the US Army Adjutant General's Office and the USAF Psychology Program.

As technical advisor and associate chief, he monitored the division's exploratory development and basic research programs in the various fields of human engineering as applied to ground, air, and space equipment and systems. Under the tutelage of Dr. Fitts, Mel did his direction-of-motion stereotype (stimulus-response compatibility) studies, certain of which results have been distilled, by others, into what is now known as "Warrick's Law." Mel was the principal technical editor of the division's publications, carrying on the Fitts' tradition of clarity and parsimony in writing. He was the first of the civilian scientists to fly at "zero G" untethered and the first to provide human factors input to the Atomic Energy Commission.

He retired as a civil servant in 1975 and as a lieutenant colonel in the USAF Reserves in 1976. He has continued to this date (1995) as a "volunteer" within the Armstrong Laboratory.

Leuba, H. R., & Rhodes, K. (1968). *Information transmission in operator reports of equipment malfunction: Methodology* (AMRL Technical Report 68-20). Wright-Patterson AFB, OH: Aerospace Medical Research Laboratory. (DTIC No. 838 161)

Lindemuth, R. W., & Tieber, J. A. (1965). *An analysis of the inertial properties and performance of the astronaut maneuvering system* (AMRL Technical Report 65-216). Wright-Patterson AFB, OH: Aerospace Medical Research Laboratory. (DTIC No. 622 443)

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Martin, W. L., & Chubb, G. P. (1970). *Human engineering considerations in designing interactive graphic displays for logistics management* (AMRL Technical Report 70-106). Wright-Patterson AFB, OH: Aerospace Medical Research Laboratory.

In 1969, Earl Sharp stumbled on to an old friend looking at some video tapes of the defensive workstation of the B-52. This fortuitous encounter led Earl to take an interest in the Electronic Warfare Officer's (EWO) workstation, which has led to a 20-year commitment to improving the design of EWO crewstations in the latest Air Force high tech bombers, including the B-52, B-1, and currently the B-2.

Earl has been the driving force behind the development of some of the most realistic bomber simulation and testing facilities in the world. Having persuaded the powers-that-be in Strategic Air Command to give him $270,000 and a B-52 training device in 1971, Earl set about putting together a high-fidelity simulation facility with the capability to collect performance data from every thrown switch, twisted knob, and CRT display. This facility has since produced valuable data which has provided the impetus for many crewstation and display design changes for the B-52, as well as being the template for a similar B-1 facility, and Earl's legacy, a B-2 test and evaluation facility.

— Klein Associates, Interview with Earl Sharp

Martin, W. L., Crawford, B. M., Kama, W. N., & Herman, J. (1968). *Quick-release fasteners for space applications* (AMRL Technical Report 68-117). Wright-Patterson AFB, OH: Aerospace Medical Research Laboratory. (DTIC No. 728 518)

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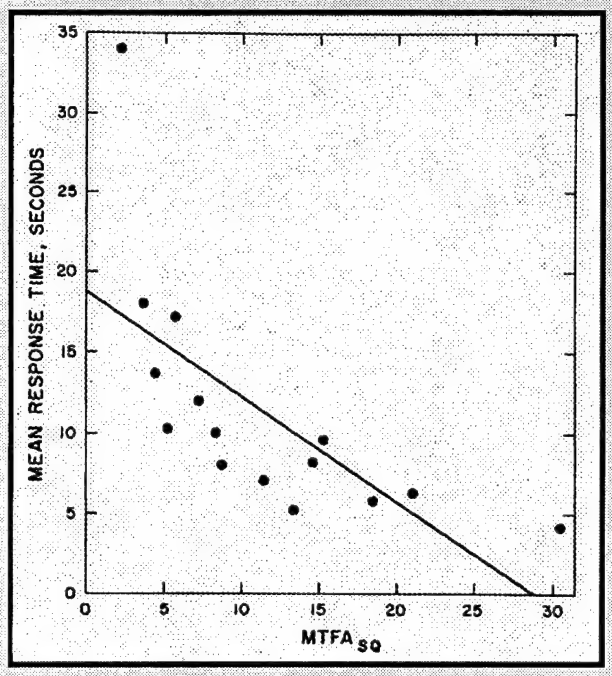

IMAGE QUALITY AND RECOGNITION TIME

Mean recognition time for human faces in a study of the effect of image quality on visual search. The work was done on a contract with the Virginia Polytechnic Institute and State University by Dr. Harry L. Snyder, Ms. Robin Keesee, Mr. William S. Beamon, and Mr. James R. Aschenbach. AMRL-TR-73-114 (1974)

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TESTING THE EFFECTS OF PANEL LAYOUT

Testing operator performance in a study of the effects of panel layout on performance in discontinuous tasks. The work was done on contract to the Philco-Ford Corporation under Task 718404 "Human Engineering for Real-Time Reconnaissance and Weapon Delivery" by R.A. Goldbeck, K.A. Wright and R.L. Fowler. AMRL-TR-70-137 (1971)

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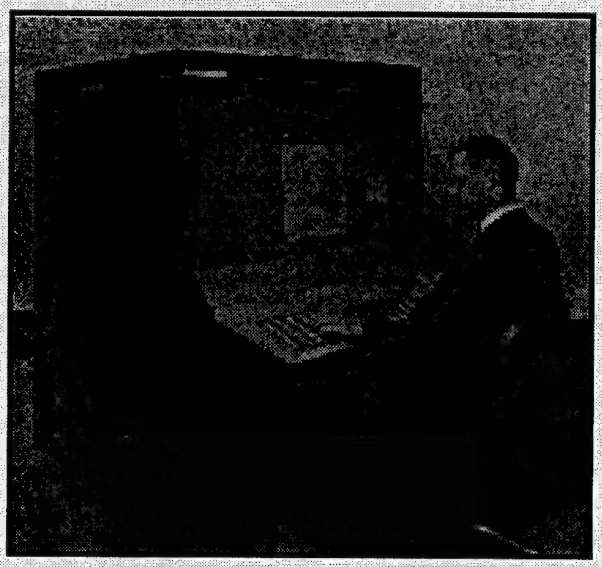

OBTAINING DATA FOR DESIGNING INFORMATION RETRIEVAL CONSOLES
A subject using an information retrieval console in a study of control panel design methodology. The work was done on contract by the Bunker-Ramo Corporation under Task 718404, " Advanced Systems Human Engineering Design Criteria." The work was performed by David Meister and D.E. Farr. AMRL-TR-66-28 (1966)

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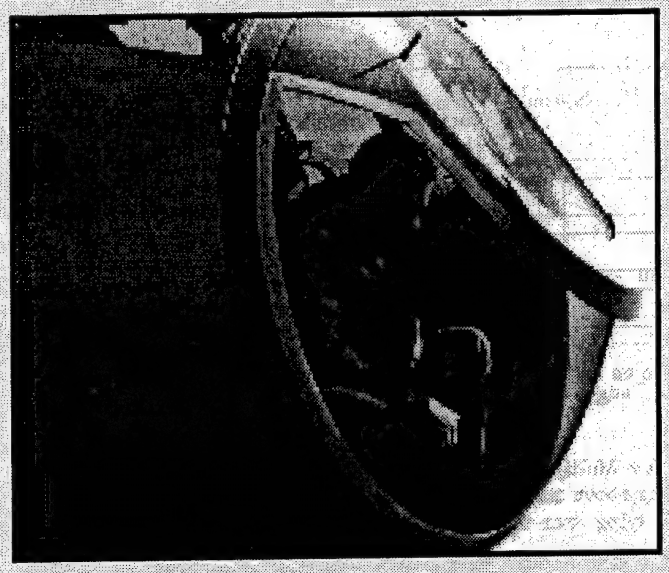

OBSERVER STATION USED IN TESTING THE EFFECT OF ILLUMINATION LEVEL ON TARGET DETECTION

Observer in the nose bubble of a WB-50D aircraft in an airborne study done in Panama on the effect of illumination level on visual target detection. This work, in support of Advanced Development Project 665A, was completed under Task 718404, "Human Engineering for Real-Time Reconnaissance and Weapon Delivery." The work was done by Dr. James L, Porterfield, Dr. Herschel C. Self, Mr. Steve A. Heckart, Maj E.P. Hanavan, and Mr. Don F. McKechnie. AMRL-TR-71-9 (1971)

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MEASURING FEMALE HANDS FOR DESIGN
Milton Alexander measuring wrist breadth in research on the anthropometry of the Air Force female hand. The work was done in support of Project 7184, "Human Performance in Advanced Systems" by John W. Garrett. AMRL-TR-69-26 (1970)

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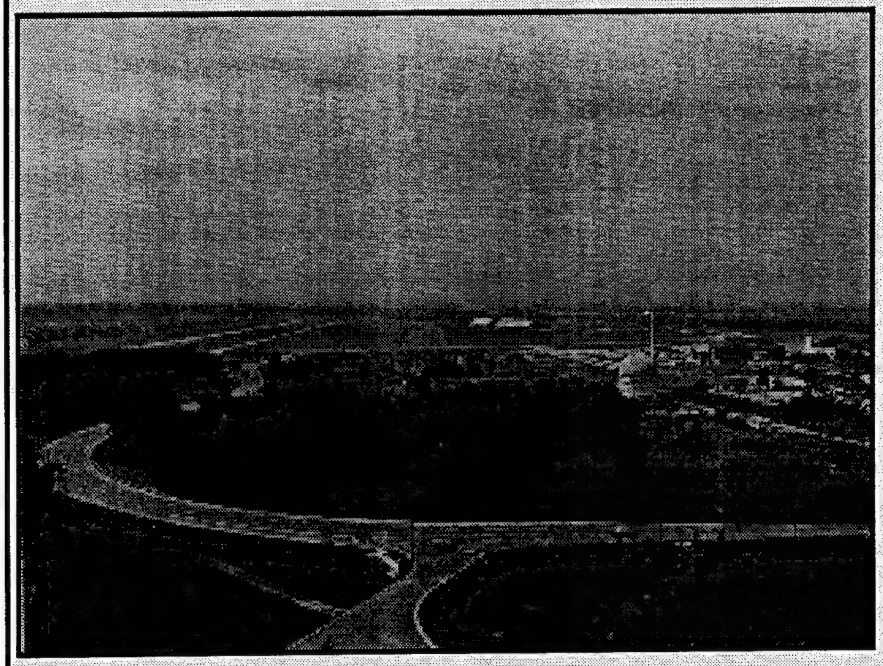

TARGET RANGE USED IN A STUDY OF COLORED SUNGLASSES

Above is the target range at Wright-Patterson Air Force Base used in a study of the effects of colored sunglasses on visual performance. The study was done on a contract to Multi-Tech Associates under Project 7184, "Human Performance in Advanced Systems." The work was conducted by Robert S. Hart. AMRL-TR-74-38 (1974)

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Seifert, D. J., & Chubb, G. P. (1973). *Computer models of man-machine survivability/vulnerability* (AMRL Technical Report 72-69). Wright-Patterson AFB, OH: Aerospace Medical Research Lab-oratory. (DTIC No. 762 528)

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Self, H. C. (1972). *Very low altitude detection of small stationary targets at very slow speeds: A simulation study using strip photography* (AMRL Technical Report 72-7). Wright-Patterson AFB, OH: Aerospace Medical Research Laboratory. (DTIC No. 754 928)

Self, H. C., & Bate, A. J. (1969). *The effect of number of allowed target choices upon the target-reporting behavior of radar observers* (AMRL Technical Report 69-96). Wright-Patterson AFB, OH: Aerospace Medical Research Laboratory. (DTIC No. 701 382)

Self, H. C., & Heckart, S. A. (1973). *TV target acquisition at various frame rates* (AMRL Technical Report 73-111). Wright-Patterson AFB, OH: Aerospace Medical Research Laboratory. (DTIC No. A006 893)

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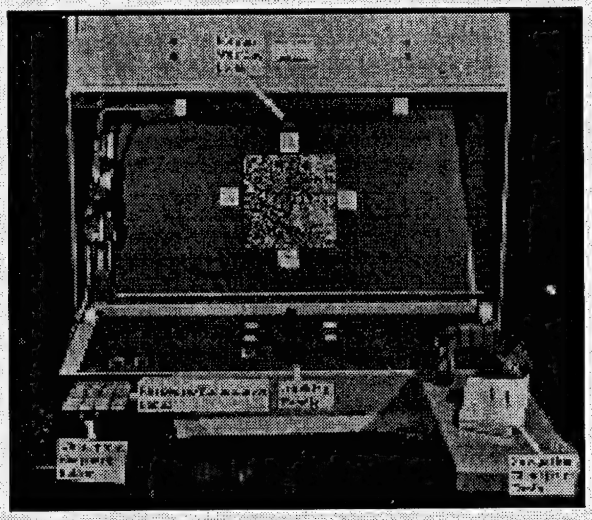

SIMULATED NAVIGATION TASK USED IN A STUDY OF WARNING SYSTEMS

The display of moving, rear-projected strip photography and the associated equipment used in a simulated aircraft navigation task in comparing the merits of malfunction warning systems. This study by Almon J. Bate under Task 718404, "Advanced Systems Human Engineering Design Criteria" supplemented an earlier 1966 study on warning systems. AMRL-TR-68-193 (1968)

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Shim, I. H., Wigby, J. I., & Mletzko, A. E. (1968). *Design study for radar land mass simulation system* (AMRL Technical Report 68-8). Wright-Patterson AFB, OH: Aerospace Medical Research Laboratory. (DTIC No. 673 908)

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Siegel, A. I., & Lanterman, R. S. (1968). *A portable test battery for comparatively evaluating operator performance in full-pressure suit assemblies* (AMRL Technical Report 68-74). Wright-Patterson AFB, OH: Aerospace Medical Research Laboratory. (DTIC No. 680 825)

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Simons, J. C. (1967). *Low-altitude recce/strike techniques, problems* (ASD Technical Report 67-17). Wright-Patterson AFB, OH: Aeronautical Systems Division. (DTIC No. 824 279)

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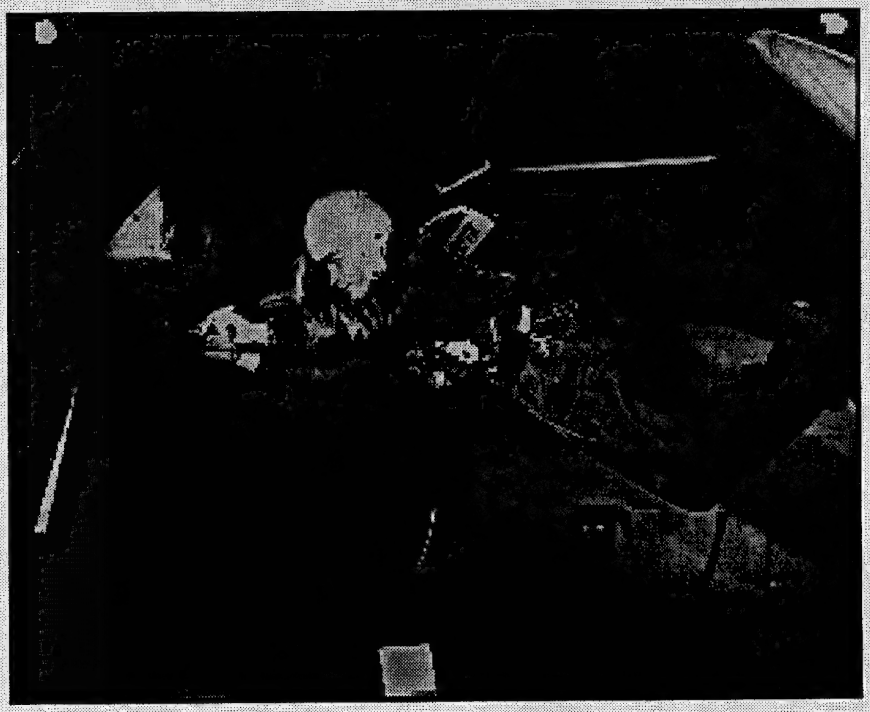
Smith, R. L., Blanchard, R. E., & Westland, R. A. (1970). *Acquisition of restore time data by subjective techniques* (AMRL Technical Report 70-76). Wright-Patterson AFB, OH: Aerospace Medical Research Laboratory. (DTIC No. 727 015)

TESTING COCKPIT WARNING SYSTEMS ON A SUBJECT BUSILY DETECTING TARGETS

Almon J. Bate testing an observer engaged in a target detection task. The study uses a moving rear-projection display image of strip photography on an information-retrieval console. The study, which compared cockpit warning systems, was done under Task 718404, "Advanced Systems Human Engineering Design Criteria" by Almon J. Bate and Charles Bates, Jr. AMRL-TR-66-180 (1967)

TOOL USE IN ZERO GRAVITY

An experimental subject floating in an aircraft flying a special flight path that produces a zero gravity condition. The study examines the effect on tool use of zero gravity. Here the subject is using a screwdriver to make instrument adjustments.



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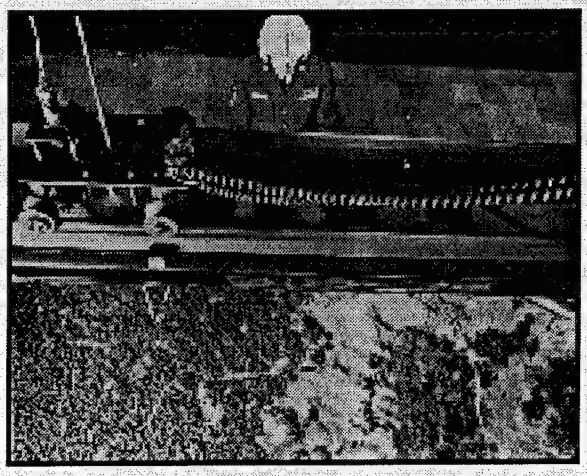

TESTING FLARE EFFECTIVENESS WITH A TERRAIN BOARD SIMULATION

An observer, using a terrain board simulation, looking for ground targets in a study that examines the effectiveness of air-dropped flares. The work was part of a joint services program on air-to-ground target acquisition, with the findings to go into the "Joint Munitions Effectiveness Manual." The work was performed by Dr. Sheldon MacLeod AMRL-TR-73-46 (1973)

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HELMET-MOUNTED DISPLAY TECHNOLOGY

Thomas Furness of the Human Engineering Division checking out an early helmet display fabricated by industry for the division. Furness, Charles Bates, Jr., and Dean Kocian began pushing the development of the technology of helmet-mounted sights, helmet-mounted displays, and visually-coupled systems in the early 1960s with funds for industrial development and laboratory investigations obtained from several sources, including the Air Force, the US Army, and NASA. Their input of ideas, enthusiasm, and funds greatly hastened the development of the technology, bringing helmet-mounted equipment into operational use by the armed forces years earlier than would have happened without their efforts. This, and related work, is continuing with the leadership of Dean Kocian, Harry Lee Task, Brian Tsou, and other laboratory personnel.

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"The lab in the sixties was not only smaller, but dramatically different. There was practically no research money. The money we did have went mostly into an OSU (Ohio State University) system research contract. The other big contract was with University of Dayton to provide experimental subjects. Most of the researchers did their own research with limited in-house funds; very little contractor research was being done at that time."

— Steve Heckart
Applications Human Engineer
Human Engineering Division

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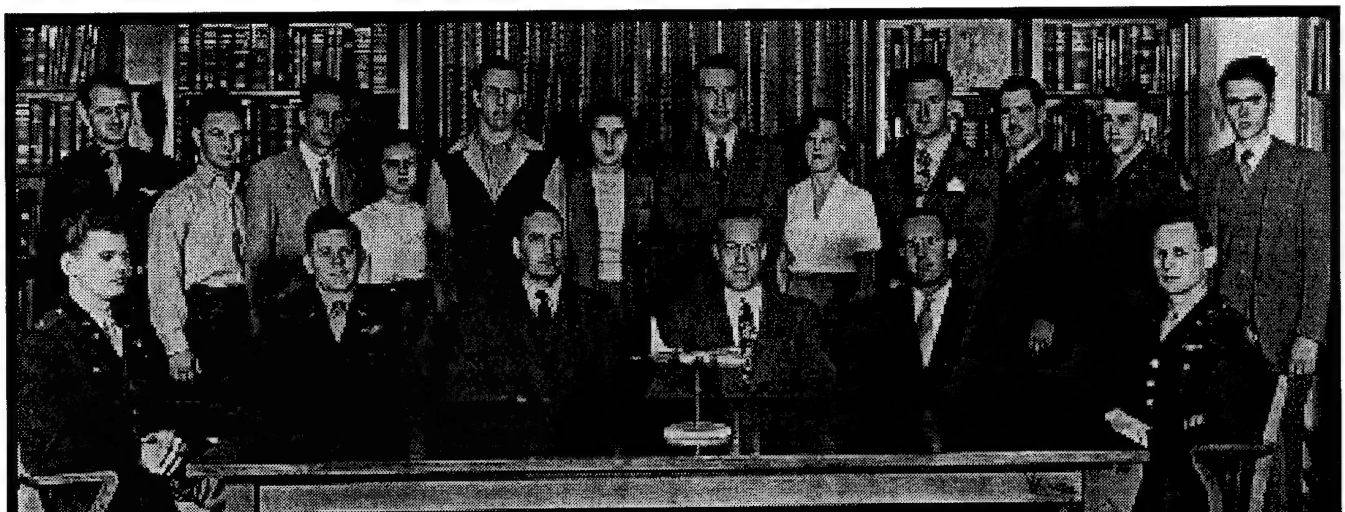
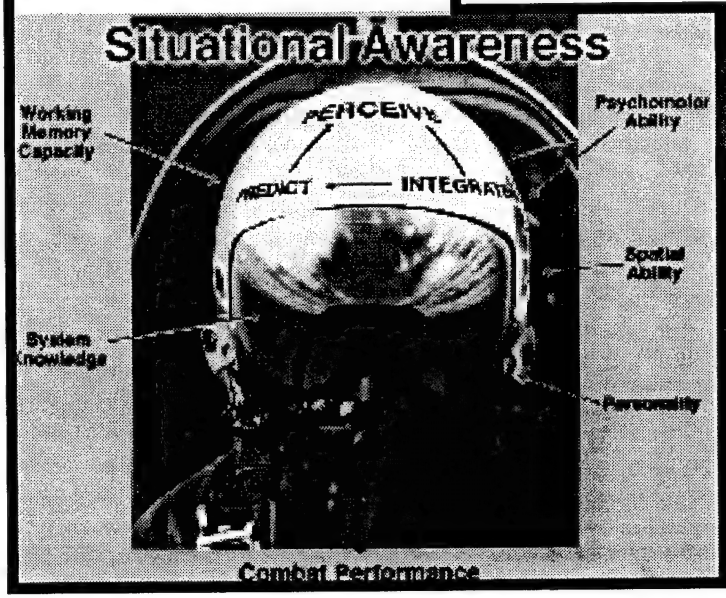


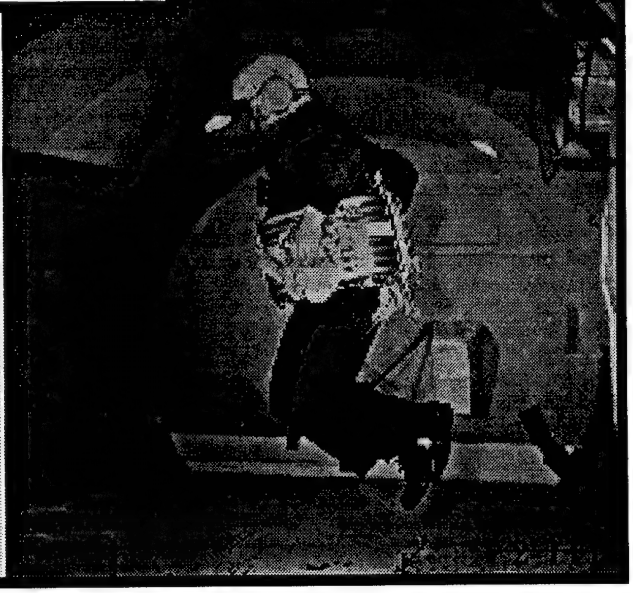
Keeping Pace with the Avionics Revolution

1975-1984

Computer technology enters a period of phenomenal growth triggering a revolution in aircraft avionics. Efforts to bring additional information into the cockpit and extend Air Force mission areas will bring about the development of controls and displays of unprecedented complexity. Resulting human engineering issues of pilot workload and man-machine interface must be addressed. The stage is set for revolutionary strides in such areas as visually-coupled systems, mental workload, and anthropometry. Dr. Julian Christensen retires from the Human Engineering Division and is replaced by Mr. Charles Bates, Jr.

1975-1984





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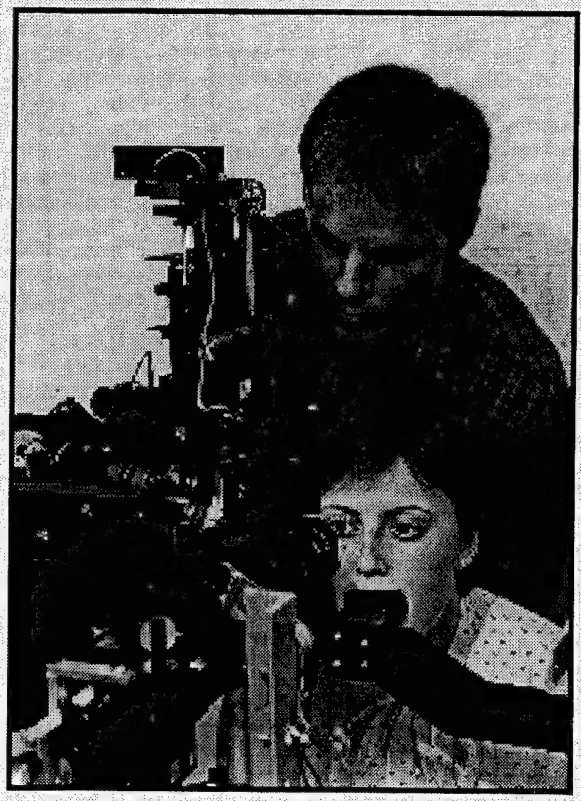

EYE TRACKING RESEARCH
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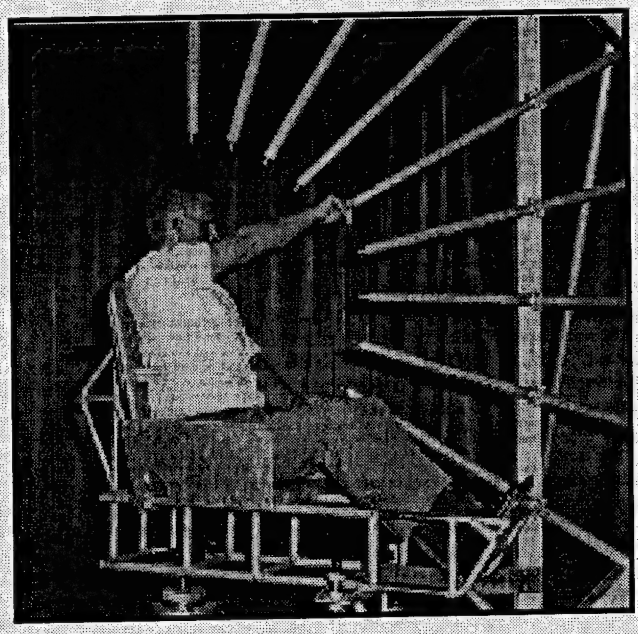

MEASURING A SUBJECT'S GRASP-REACH ENVELOPE

Subject reaching along a 30-degree line in the left 15-degree plane in a study to determine the 5th, 50th, and 95th percentile grasping-reach envelopes in three dimensions for men and women. The data were collected to serve as a guide to the placement of critical hand-operated controls for the seated operator. The work was done by Kenneth W. Kennedy under Workunit 71840832, "Design and Evaluation of Work Stations." AMRL-TR-77-50 (1978)

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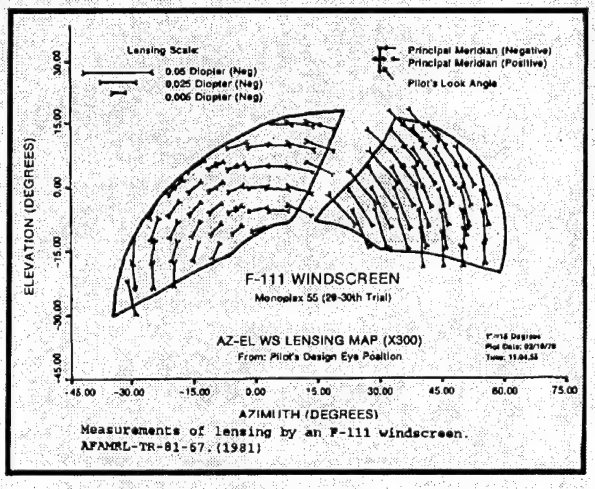
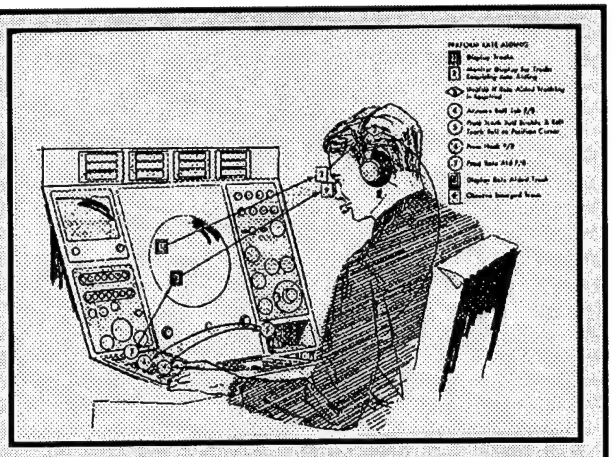


AN EXAMPLE OF WINDSCREEN OPTICAL DISTORTION

Illustration of the lensing produced by an F-111 windscreen in a study of windscreen distortion. The study was conducted in order to develop a computer analysis of the distortions to enable aiming correction for optical distortion in visually-coupled systems. The work was done by Major Rick Seid. AFAMRL-TR-81-67 (1981) (Task 718418)

A LINK-ANALYSIS SAMPLE

A sample link analysis extracted from a human engineering procedures guide by Charles W. Geer of the Boeing Aerospace Company developed under Workunit 71841212. AFAMRL-TR-81-35 (1981)



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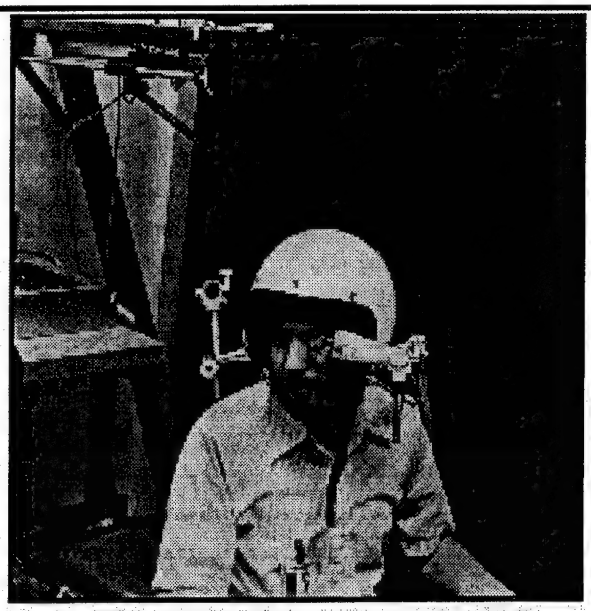

MEASURING THE PERFORMANCE OF A VISUALLY-COUPLED SYSTEM

Measuring head position and aiming accuracy in a visually-coupled system to examine the engineering interface. The work was done under Project 7184, Workunit 71842005 by Sheldon MacLeod of AMRL and David B. Coblintz of McDonnel Douglas. AMRL-TR-79-32 (1979)

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Geer, C. W. (1981). *Human engineering procedures* (AFAMRL Technical Report 81-35). Wright-Patterson AFB, OH: Air Force Aerospace Medical Research Laboratory. (DTIC No. A108 643)

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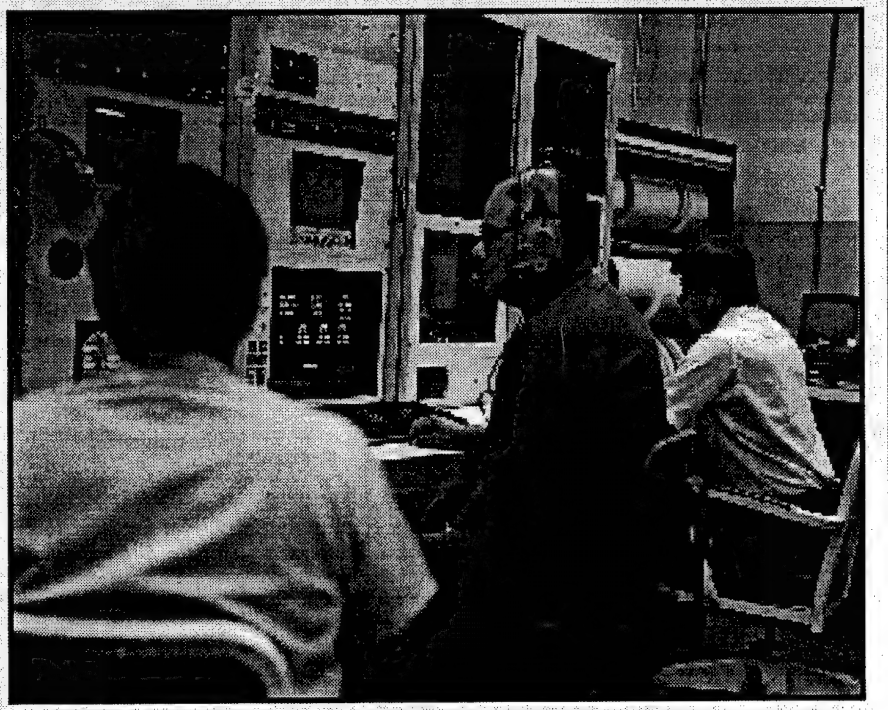
SUBJECT AT A SIMULATED B-52 WORKSTATION

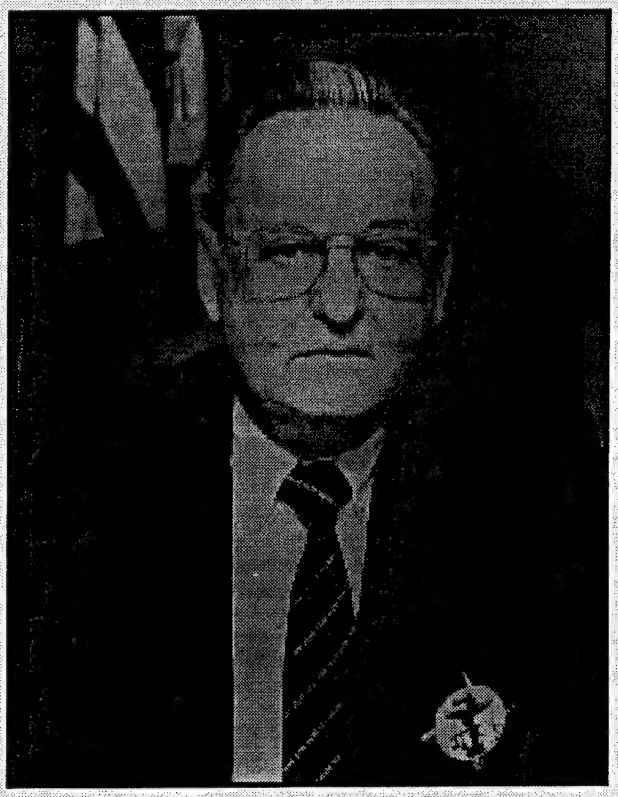
MSgt Al Chapin of AMRL at a workstation in a simulation of the B-52 bomber's Offensive Avionics System (OAS). This simulator was used for several years by Earl Sharp and his associates in the Human Engineering Division to study the deficiencies of the system and provide suggestions for modifications and design improvements. This picture was taken in 1980. (Task 718410)



Charles Bates, Jr.

Chief, Human Engineering Division

1975 to 1991



Charles Bates, Jr., following a tour in the US Army Air Forces, received his Masters Degree in Industrial Psychology from Kansas State University. Subsequent graduate studies involved industrial training in side-looking radar and photo interpretation.

Starting in 1956, he engaged in research directly supporting Air Force weapon system development. After nearly 35 years of government service entirely devoted to the Armstrong Laboratory at Wright-Patterson Air Force Base, Ohio, Bates retired as Director of the Human Engineering Division of the Crew Systems Directorate.

Under Bates, the division performed research dealing with a wide range of human performance issues in Air Force systems, including programs in workload measurement, visually coupled systems, strategic aircraft crew station design evaluation, effects of microgravity on vision, cockpit design support technology and basic research in human visual performance.

Bates was a key factor in the success of many different projects during his career. From his start in the Crew and Systems Branch, he was involved in crew station design for the Snark, Atlas, Navaho, B-52, B-70, Skybolt, and Hound Dog Programs. Participation in the development and test activities of these programs led to a research project to quantify the contribution of the human component to system reliability.

In 1962, Bates was promoted to Chief, Performance Requirements Branch, where his primary responsibility was human engineering support of Air Force advanced system development, including analysis and experimental activity on human performance problems peculiar to advanced systems. Bates was project engineer for the human performance aspects of the Manned Orbiting Laboratory Program. His branch initiated the early work in visually coupled systems, including the development of the first airborne qualified helmet-mounted sight and helmet-mounted display, and provided the initial human performance data for multisensor and real-time reconnaissance program development. In 1975, Bates was promoted to Director of the Human Engineering Division and then selected for the rank of Senior Executive Service in August 1983.

Bates was the recipient of several performance and professional awards, including the Air Force Systems Command Distinguished Civilian Service Medal and the Presidential Meritorious Executive Rank Award. A past Chairman of the Aerospace Medical Panel of the Advisory Group for Aerospace Research and Development of the North Atlantic Treaty Organization, Bates held four patents in the areas of visually coupled systems and helmet-mounted displays.

Ginsburg, A. P. (1983). Direct performance assessment of HUD display systems using contrast sensitivity. In W. L. Martin (Ed.), *Optical and human performance evaluation of HUD systems design* (Report No. Air Force Aerospace Medical Research Laboratory-Technical Report-83-095, pp. 55-66). Wright-Patterson AFB, OH: Air Force Aerospace Medical Research Laboratory. (DTIC No. A140 601)

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"As far as I know I am the only person to have done human experiments in the Thomas domes. Volunteers were exposed to low levels of carbon monoxide as they slept. They were in there for about ten hours—eight hours of sleep and two hours of performace tests. The reason for the study was that a report out of Stanford had stated that 50 parts per million affected performance. At that time the military limit was 100 parts per million per eight hour period, so they were concerned about performance decrements, as well as the possible need to make changes in workplaces and work shifts. We found no performance effect at all. We had essentially replicated the procedure of the Stanford scientist, so he rechecked his data and found an error. He retracted his findings. That was a big success for us."

— Robert O'Donnell, Chief
Workload and Ergonomics Branch
Human Engineering Division

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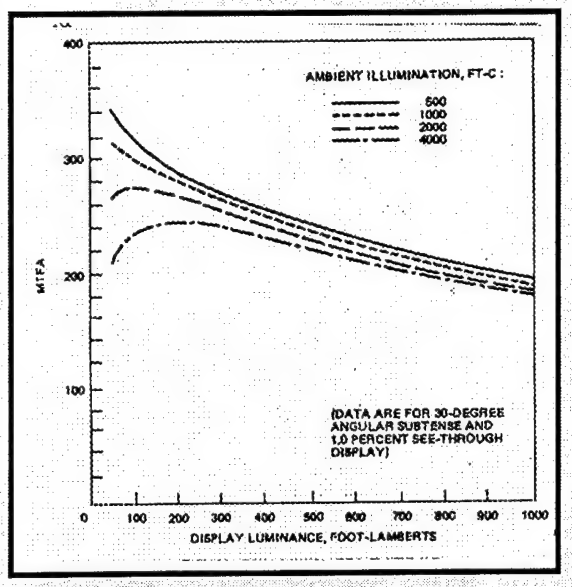

THE MODULATION TRANSFER FUNCTION OF A DISPLAY

Modulation transfer function area (MTFA) as a function of display luminance and ambient illumination. This graph, from "Binocular Rivalry in Helmet-Mounted Display Applications" is one of several graphs in this research study done for AMRL by M.L. Hershberger and D.F. Guerin of the Hughes Aircraft Company. This study is one of many conducted over a period of several years by various organizations in support of the Human Engineering Division's extensive research and development program on helmet-mounted display systems. AMRL-TR-75-48 (1975) (Task 718411)

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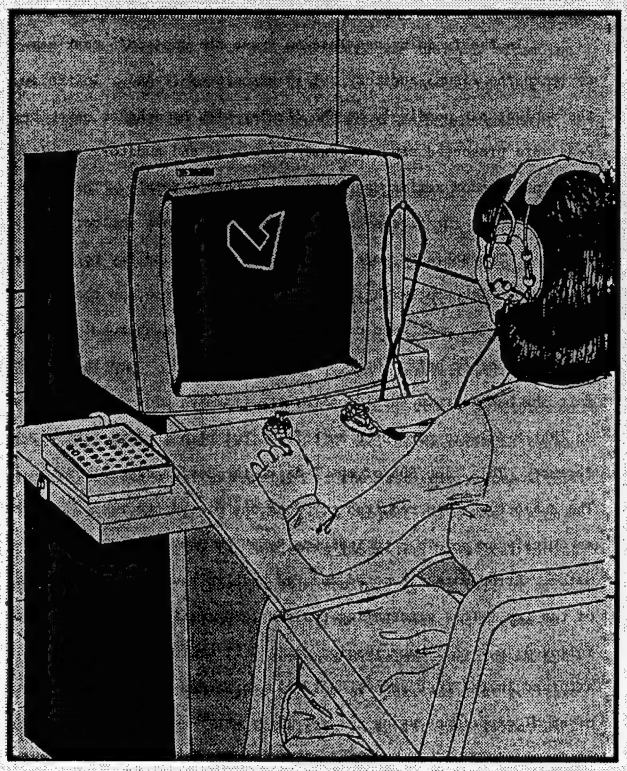
Korna, M., & Aume, N. (1980). *Designer's guide for the panel program* (AFAMRL Technical Report 80-124). Wright-Patterson AFB, OH: Aerospace Medical Research Laboratory. (DTIC No. A093 989)



EVALUATING MODALITY EFFECTS IN SCANNING NONVERBAL INFORMATION

Sketch of a subject using a computer display in a study measuring modality effects in scanning nonverbal information to obtain evidence for multiple memory codes. The work was performed under Workunit 71841407 by Reuben L. Hann. AMRL-TR-79-53 (1979)

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"We have a fairly broad program in our division that is built on the foundation that Paul Fitts had laid when he first formed the organization 40 years ago. Much of his original work dealt with the solution of operational problems that he found occurred during World War II. From that work he developed general design principles that were then, in turn, translated into standard design practice, some of which are still in use today. The systems he worked on were comparatively very crude compared to the design challenges today; however, the basic paradigm still works."

—C. Bates, May 1985, "Human Engineering, Yesterday and Today," Civilian Employees Reporter

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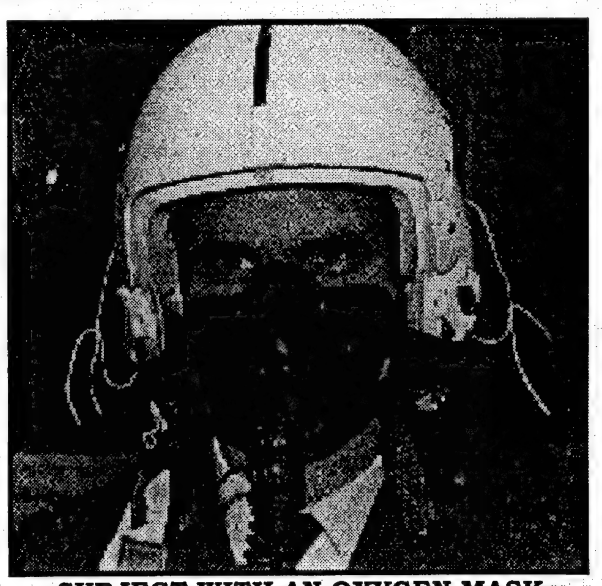
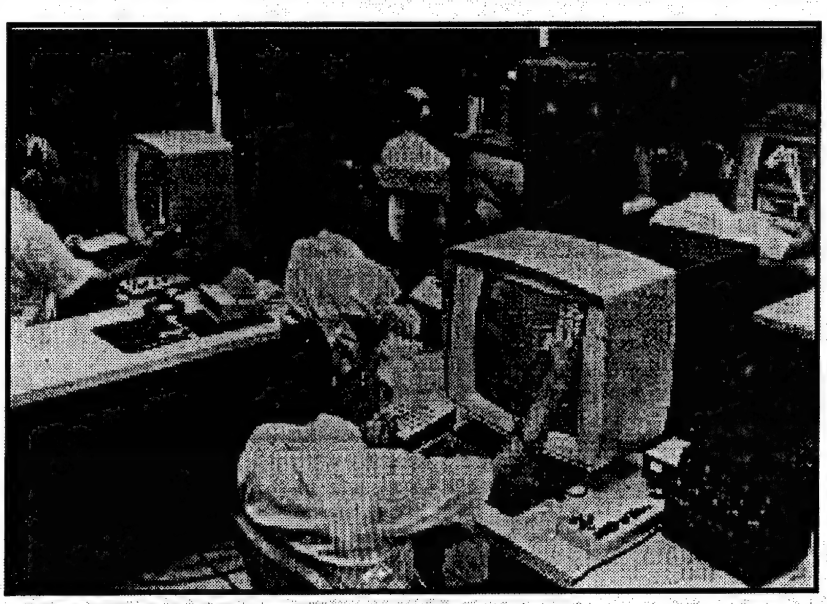


SUBJECT WITH AN OXYGEN MASK IN TESTS FOR FITTING AND EVALUATION DATA

Front face view of a subject wearing an MBU-12/P oral-nasal oxygen mask in a study on the anthropometric sizing, fit-testing, and evaluation of this mask for air crew members. The work was done under Project 7184, Workunit 71840826. The researchers were Milton Alexander of AMRL and John T. McConville of Anthropology Research Project, Inc. AMRL-TR-79-44 (1979)



MULTIPLE OPERATORS CONTROLLING A REMOTELY PILOTED VEHICLE

Multiple operators in a simulation of remotely operated vehicles in a study designed to examine control smoothing and automatic heading correction. The work was done under Workunit 71841402 by Robert G. Mills, Robert F. Bachert, and Nilss M. Aume. AMRL-TR-75-87 (1975)

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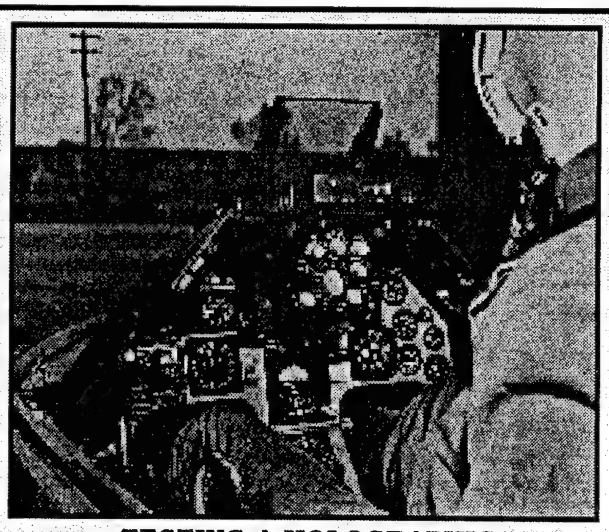

TESTING A HOLOGRAPHIC HEAD-UP DISPLAY (HUD)

Testing a pilot in the cockpit of a YF-16 aircraft looking through the head-up display (HUD) in a study of diffractive optics. The goal was to determine the utility of both reflective and transmissive holographic optical elements for extending the information display capability of fighter aircraft. The study was done on contract under Workunit 71840448 by W. N. Lewis, D.H. Close, J.G. Cook and R.S. Jacobs of the Hughes Aircraft Company. AMRL-TR-76-119 (1977)

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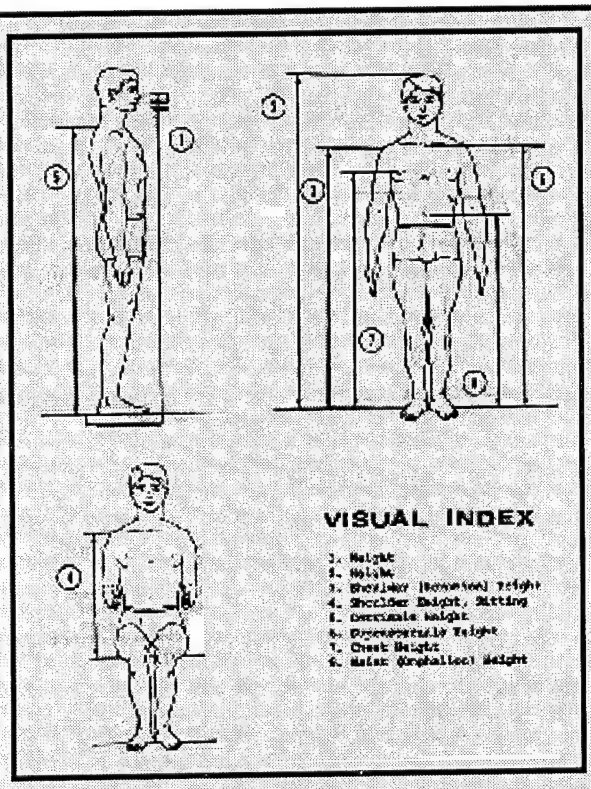

MEASUREMENTS USED IN A HEIGHT-WEIGHT SIZING MANUAL

Some of the 71 different measurements taken for a revised height-weight sizing manual for protective flight garments. The work was done under Workunit 71840826 of Project 7184 by Milton Alexander, and by John McConville and Ilse Tebbetts of Anthropology Research Project, Inc. AMRL-TR-79-28 (1979)

In 1983, the Strategic Air Command asked my group to build a simulator facility for the new B-1 bomber, which was under construction, but for which there was no training device. We built them two simulators to serve as interim trainers while the production trainers were being produced. While these were being fielded, we built another, higher fidelity, defensive simulator and began a similar operation for the B-1 as we had done for the B-52. Later the two fielded units were returned to the lab and served as experimental platforms for all B-1 crew positions. This group is now working on a similar device for the B-2.

— Earl Sharp. Program Engineer
Human Engineering Division

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MEASURING ISOMETRIC FORCE CAPABILITY FOR A FEMALE STRENGTH ATLAS

Dr. Joe McDaniel measuring a five-second isometric force exertion by an Air Force enlisted woman in one of the six directions and seventy-six handle locations used in compiling a strength atlas. (1978-1980) (Task 718408)

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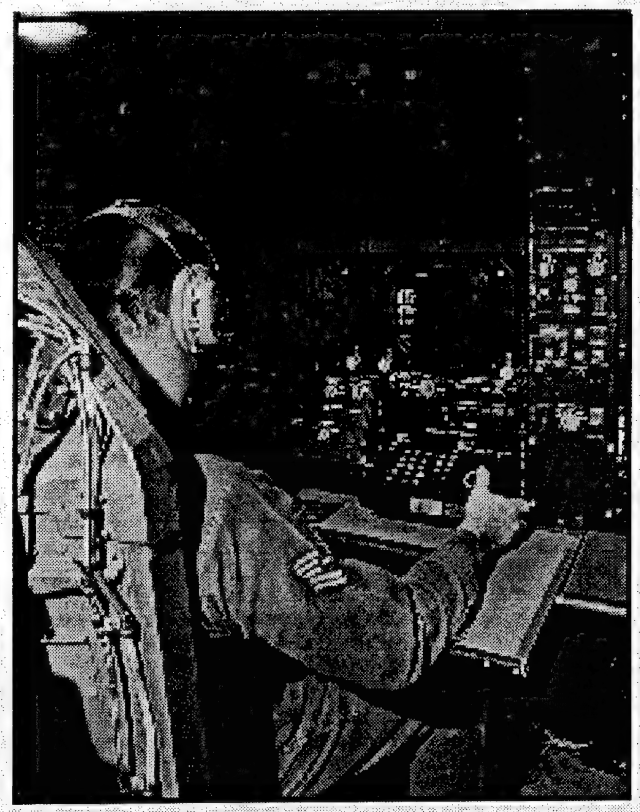

TESTING AN OBSERVER AT A SIMULATED B-52 BOMB-NAVIGATION STATION

An observer working at the bomb-navigation station of a B-52 aircraft simulator in the Armstrong Laboratory. This station was part of the Offensive Avionics System (OAS) on the B-52. The Human Engineering Division performed human factors-oriented exercises with the system and conducted experiments and analyses of human and system behavior to obtain design recommendations for improving it. The work was done by Earl Sharp and coworkers in 1974-1976. (Task 718410)

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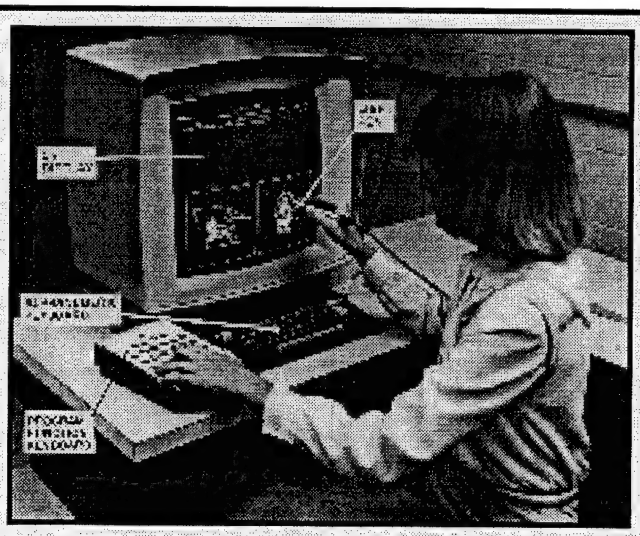
DEVELOPING OPERATIONAL PROCEDURES FOR COMBIMAN

Susan M. Evans from the University of Dayton Research Institute working with a display used in developing a user's guide on operational procedures for the COMBIMAN program. The work was done under Workunit 71840824. COMBIMAN is the acronym for COMputerized BIomechanical MAN-model, a computer-generated manikin of the human body representing its various and variable dimensions and motion characteristics. COMBIMAN was developed earlier for the Human Engineering Division. This model has been revised several times since this report by Susan M. Evans. AMRL-TR-78-31 (1978)



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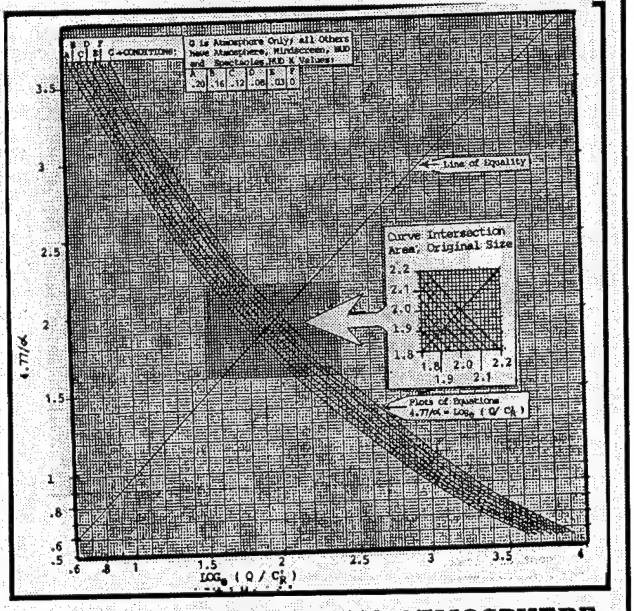

CONTRAST LOSS DUE TO ATMOSPHERE, WINDSCREEN, AND SPECTACLES

One of the tutorial examples in a theory paper showing how to determine airborne contrast loss due to the atmosphere, the aircraft windscreen, and spectacles. A paper by Herschel C. Self; one of several papers in a joint AFAMRL-ASD (ENA) technical report edited by Wayne Martin. AFAMRL-TR-83-095 (1983) (Task 718418)

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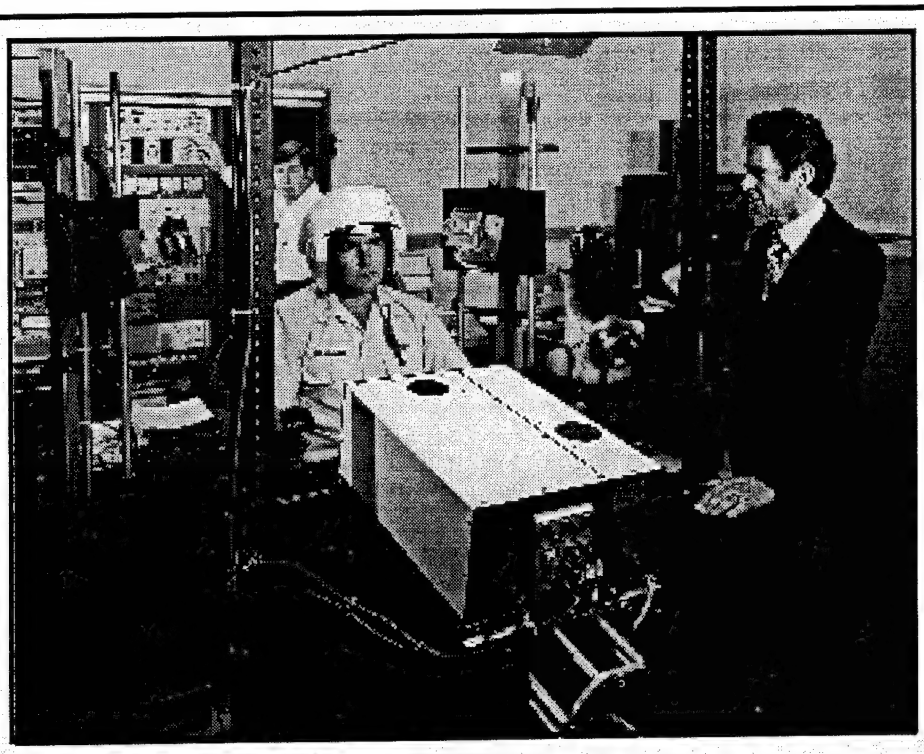
One of Earl Sharp's first projects on his newly developed B-52 EWO simulator was to redesign it based on available anthropometric data. This project was spurred by his observations that the crews were sometimes unable to reach or see important components of the workstation. Simply by applying an existing database of reach data with data about forces required to operate certain switches or knobs and dials, Earl came up with a more ergonomically sound workstation.

In order to test the new design concepts, Earl recruited crews to run as subjects in highly realistic mission scenarios which consisted of real mission briefings, the mission itself, and the debrief, to provide the crews with the most real experience possible. SAC provided the details of the up-to-date threat types from Vietnam (at the time) to challenge the crews and make them act as if they were really there. The crews reported that after about 30 minutes, they had forgotten they were in a simulator. They also reported that the realistic missions provided them with better training than some of the simulator training conducted in the wings.

Some of Earl's discoveries were frowned upon by SAC. Earl would discover what really went on in the aircraft rather than what doctrine dictated or what SAC thought was happening. He was able to guarantee the subjects' anonymity and confidentiality while they were being tested and so the crews acted as they would in the real aircraft. This brought credibility and respect to Earl's findings from the crews and SAC.

— Klein Associates
Interview with Earl Sharp



EYE TRACKING PERFORMANCE

Capt Al Dickson is the experimental subject, James L. Porterfield is the experimenter, and Don Monk is adjusting the equipment in an investigation of eye tracking performance with the Honeywell Remote Oculometer. This work was done in 1978.

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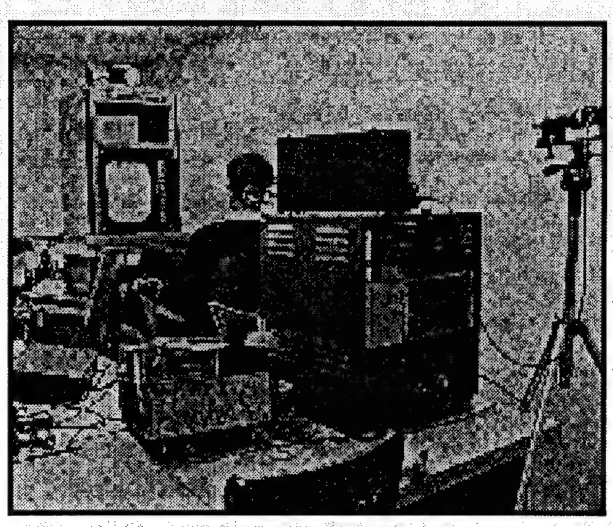

TESTING FOR AN OBSERVER'S MODULATION DETECTABILITY THRESHOLD

A subject observing the display in a study of the modulation detectability thresholds for line-scan displays. This contract research was done for AMRL by Robin Keesee of the Virginia Polytechnic Institute and State University. AMRL-TR-76-38 (1976) (Project 7184)

Shortly after being assigned to the newly formulated Visual Display Systems Branch (May, 1974), under the direction of Thomas A. Furness, I was asked to consult with Avionics Laboratory personnel at WPAFB involved with detecting and monitoring the presence of satellites in deep space. By that time, there were sufficient pieces of disintegrated satellites, as well as functional satellites launched by this country and others, that the Avionics Laboratory, in conjunction with Lincoln Labs, was proposing to build GEODSS (Ground Electro-Optical Deep Space Surveillance System), a satellite detection, tracking, and cataloging system. The plan was to build a few tracking stations at selected sites around the globe which would house high-powered telescopes, slaved to the movement of the starfield, having very sensitive TV cameras at the image plane. The video information was to be displayed on high-resolution displays which would be monitored by operators who would identify anything that moved as either a satellite or noise. Problems of vigilance and visual differentiation between a real satellite and artifacts of electronic noise were mixed with boredom and visual fatigue to produce a very challenging human task.

A short time earlier, Larry Scanlan at the University of Illinois at Urbana-Champaign had produced a PhD dissertation on "time compression" under the contractual support of the Air Force Office of Scientific Research. His research, and that of C.T. White of the Naval Electronics Laboratory, nearly 20 years earlier, demonstrated greatly improved target detection performance using the coherent motion cues provided by a time-compressed display. White had filmed successive scans of a radar display and projected them back at a standard movie frame rate, thus making the coherence of target movement much more apparent. Scanlan used a computer-driven plasma panel display to generate the stimulus material and explored the effects of various time-compression ratios and number of stored frames on detection time.

An inexpensive dual-screen black and white TV had just come on the commercial market, having approximately five-inch and eight-inch screens, together with a "one-shot memory" video disk for recording and displaying on the smaller screen, single frames of video for study by sports enthusiasts. We bought seven of these devices, and had the video disks pulled out of them and wired so as to be able to manipulate the time between stored frames, the number of times a stored frame was displayed before the next one was presented, and the number of frames stored. Bill Kama and I (with the help of Maryann Howes of SRL) were in the process of generating experimental stimulus materials using a satellite/starfield simulator the Avionics Laboratory had fabricated, in which sky background, satellite magnitude (brightness), movement and viewing distance could be controlled. We wanted to use the video time compression equipment in our laboratory to determine the best combination of parameters, prior to using it on real satellite imagery. However, once the Avionics Laboratory witnessed the dramatic improvement in detection time and ease of use, they insisted on taking the rack-mounted hardware to their Lincoln Labs test site at White Sands, New Mexico. After our brief indoctrination of the workings of the system with real satellite imagery, the Avionics Lab and Lincoln Lab personnel were so enamored by the capability they saw, they refused to release the device for our further testing. They used it to hone the time-compression parameters in a computerized version of the device, which is still in use today in GEODSS sites such as that on Maui, Hawaii.

— Wayne L. Martin, Chief
Visual Display Systems Branch
Human Engineering Division

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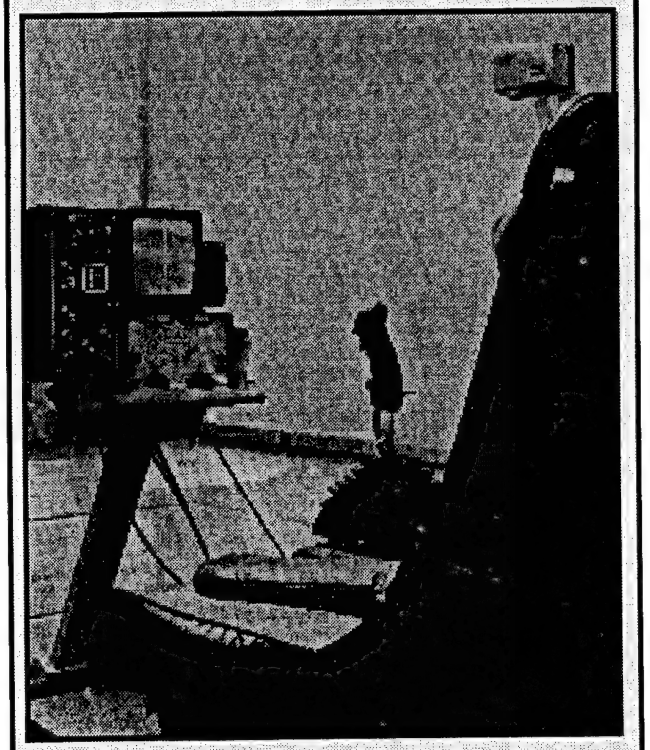

WORKSTATION FOR A GUIDED BOMB SYSTEM

Operator's workstation of the weapon delivery simulator for the GBU-15 TV-guided bomb used to evaluate alternative video imagery processes in jammed and unjammed environments. Researchers were Robert G. Mills of AMRL, Franklin T. Hutson and Walter B. Hartman of the Air Force Wright Aeronautical Laboratories, and Edwin G. Meyer, Herbert Navarro, Constance M. Hoyland, and Robert R. Covelli of the System Development Corporation. AFAMRL-TR-81-45 (1981) (Project 6893)

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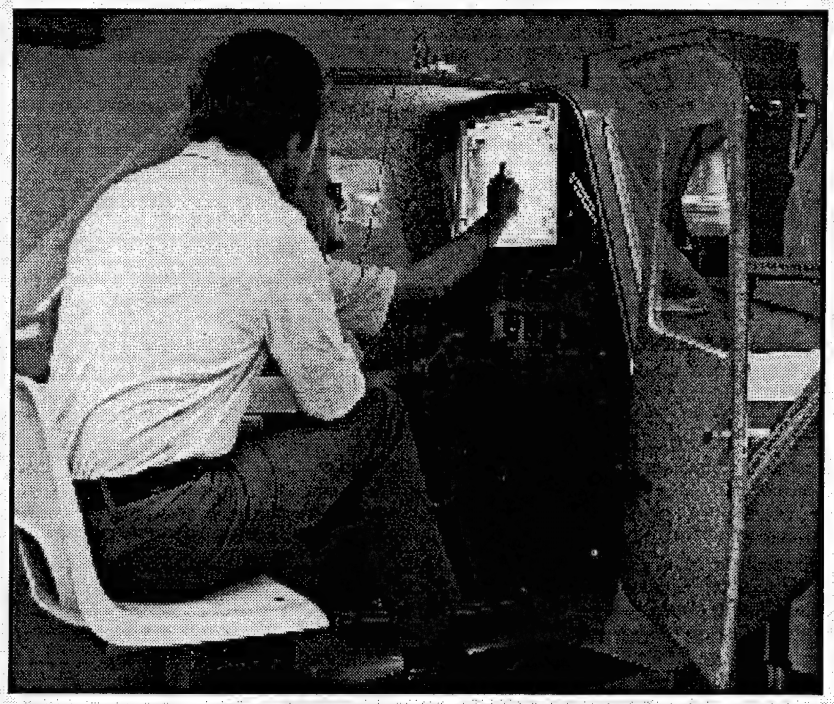

A SUBJECT IN A WORKLOAD STUDY

Gary Reid observing a subject at a display in a study examining both physiological and psychological measures of workload in a simulation of a general aviation cross-country instrument flight. This work was done in 1982. (Task 718414)

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"In 1969 I found myself working in the lab with a new boss, Dick Ravanell, an Air Force major. He was a fighter pilot and knew the ins-and-outs of high speed maneuvering and its effects on the pilot. I had worked with zero-G environments and was aware of the potential effects on human performance under different G forces. We began to anticipate the potential impact on the pilot of the new, higher G loads that the next generation of fighter aircraft were going to be able to withstand."

— Phil Kulwicki, Technical Director
Crew-Centered Cockpit Design
Human Engineering Division

"My most enjoyable project was working on the pre-cursor of the Manned Orbiting Laboratory (MOL). When NASA was set up, that research was turned over to them, but until then the Air Force had a program in the area. I worked on it intermittently for two or three years as the Human Engineering focal point on the MOL team. One of the things we investigated was whether humans could operate outside of a spacecraft to make repairs—what was later called the "space walk"— and to determine what kind of tools they would need. This was a very fundamental question in those days. The lab had access to C-131 and C-135 zero-G aircraft, and many people were involved in studying what kind of tools would be required — such as torque-canceling socket wrenches — to work in that kind of environment."

— Steve Heckart
Applications Human Engineer
Human Engineering Division

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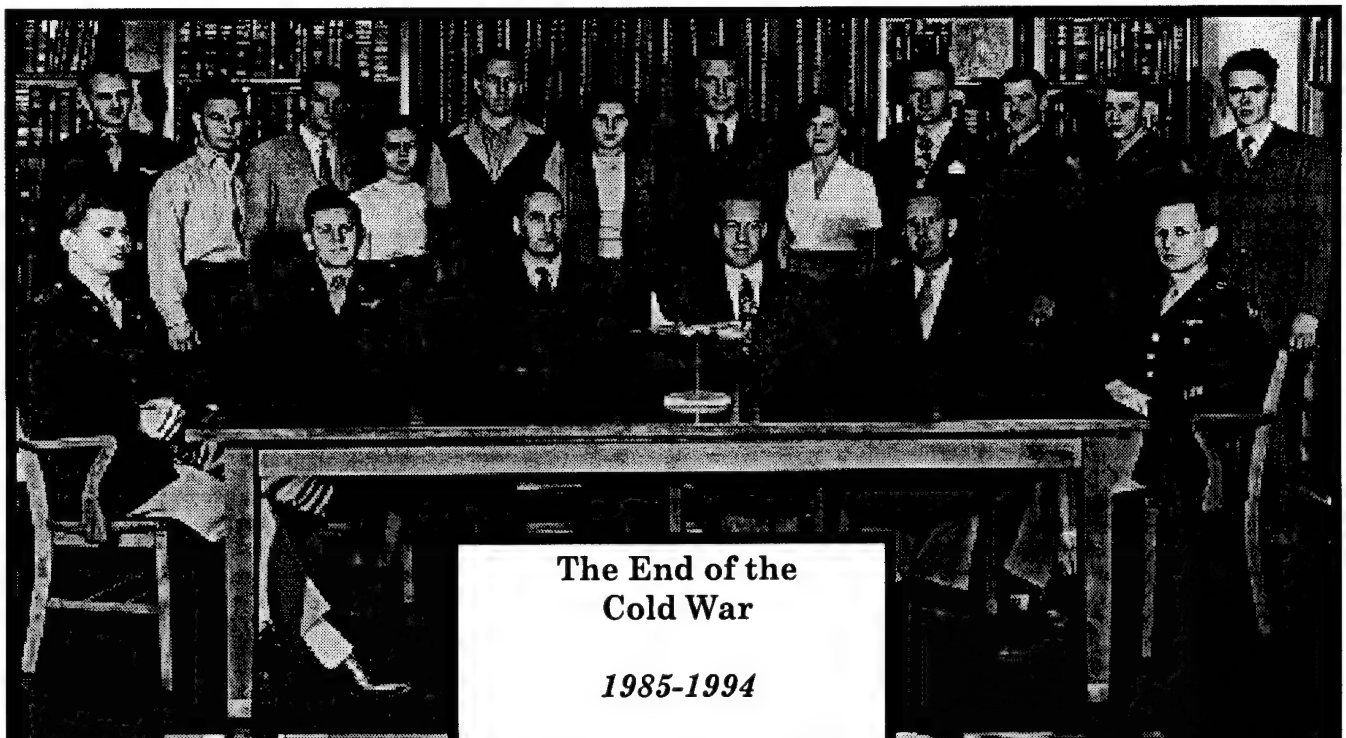
The VCASS (Visually-Coupled Airborne Systems Simulator) helmet is an example of an incredible design option. The helmet's miniaturized electronics project an image onto a screen approximately two inches in front of the pilot's eyes and offer a view of what is outside the cockpit. Flight data are superimposed over the scene. Using that information, the pilot activates aircraft systems with eye and hand movements and also voice commands. This replaces the pushing of knobs and buttons which are nearly eliminated from the cockpit.

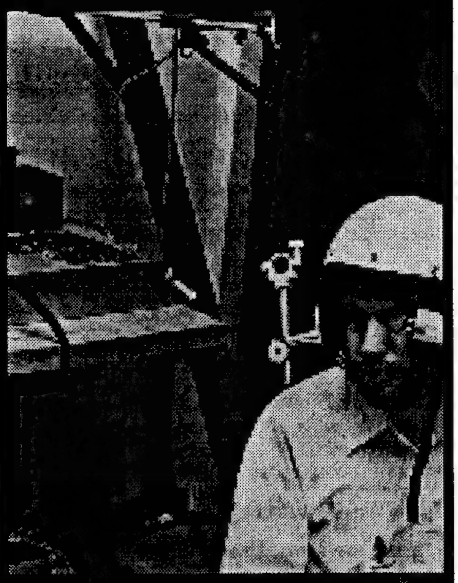
—May 1985, "Human Engineering, Yesterday and Today," Civilian Employees Reporter

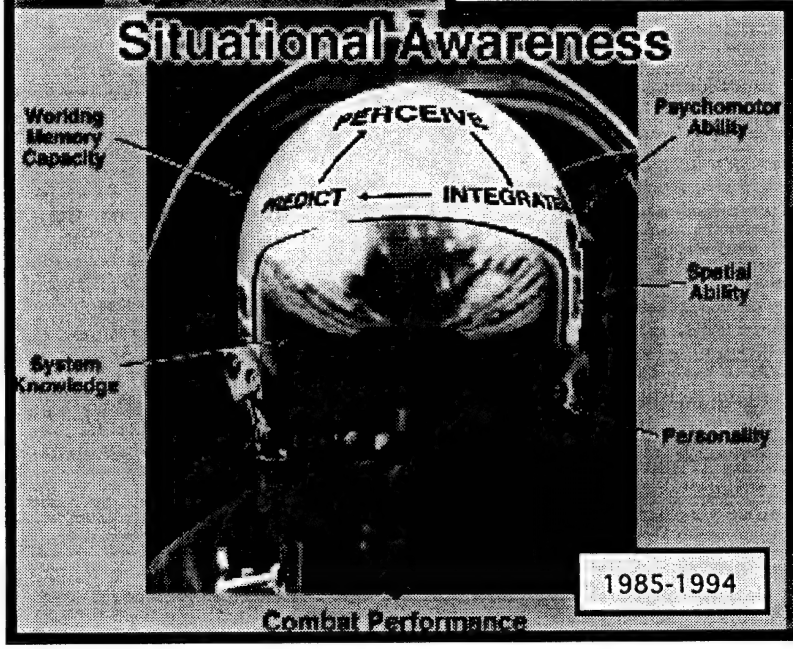


The End of the Cold War

1985-1994

The military build-up of the Reagan years will prove too much for a bankrupt Soviet Union which splinters, surrendering its super-power status. The Air Force responds by concentrating efforts on "global reach, global power." Air Force laboratories are subject to the inevitable post-Cold War drawdown, and research programs are recast to emphasize dual-use and commercialization potential. The user-oriented Bates years at the Human Engineering Division continue until his retirement in 1991 when he is replaced by Dr. Kenneth R. Boff.





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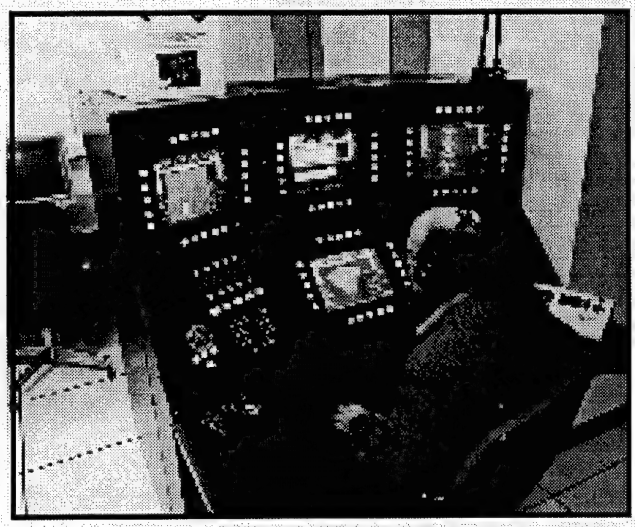
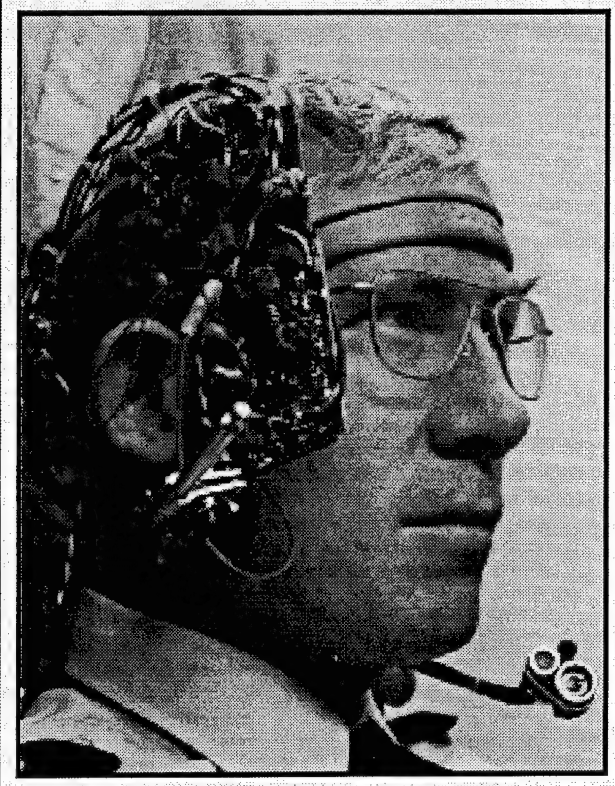


A LAB SCIENTIST AT THE SABER STATION
Gilbert G. Kuperman working at a repeater station of the Strategic Avionics Battle management Evaluation and Research (SABER) facility which supports in-house exploratory development in sensor-mediated target acquisition. The work at SABER aids the design and integration of advanced avionics capabilities including integrated multi-sensors, automatic target cuers and recognizers, precision strike, and mission planning. (1989) (Workunit 71841044)



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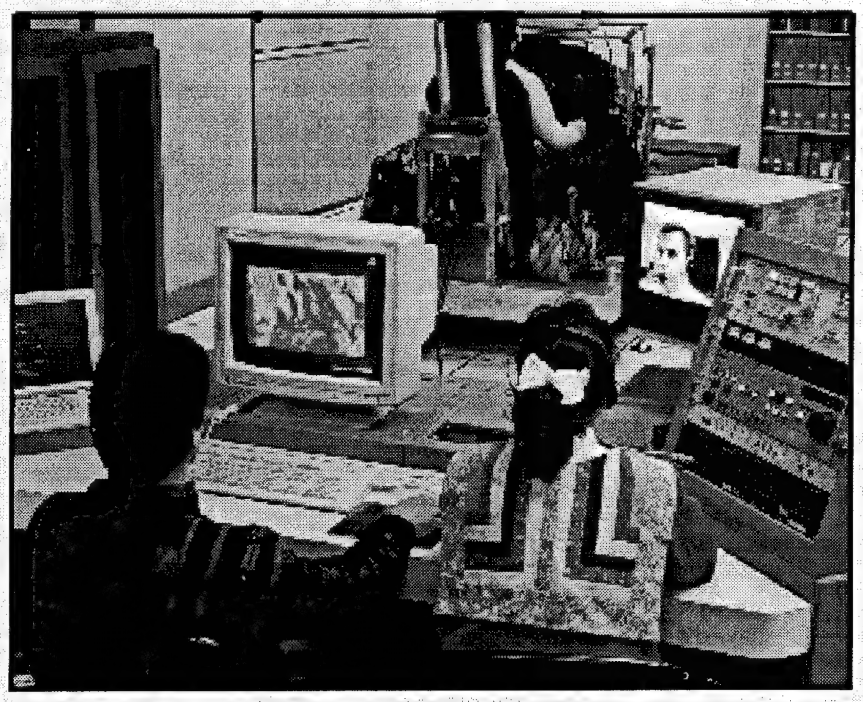

CREW-CENTERED ANALYSIS AND DESIGN SUPPORT

The Crew-Centered Analysis and Design Support Laboratory is the focal point for demonstrating advanced concepts in crewstation design and evaluation technology for the Crew-Centered Cockpit Design (CCCD) project. The rapidly reconfigurable Engineering Design Simulator (EDSIM), as seen here, is used for rapid prototyping and design evaluation. Using the EDSIM, under part-task/full-mission scenarios, various data are collected to verify and validate crewstation designs including mission events and human performance measures (aircrew actions, audio, visual, and physiological responses). (Workunit 28290309)

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Dr. Fitts is the premier leader in the analysis and solution of World War II crew station design issues which, in turn, led to the founding of human engineering technology. We are indeed honored to be able to honor him by naming a modern human engineering research facility in his name.

— Col George C. Mohr, AFAMRL Commander, May 1985, "Pioneer in Human Engineering is Due the Ultimate Honor," Civilian Employees Reporter

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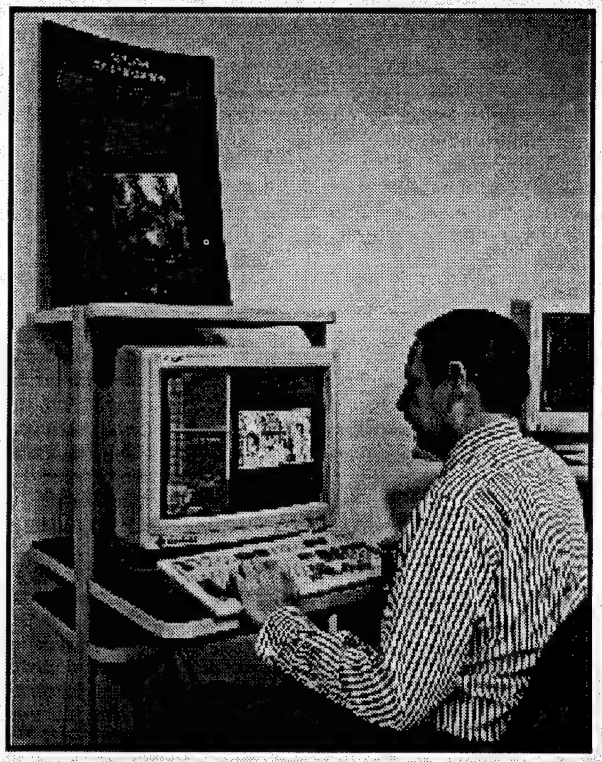
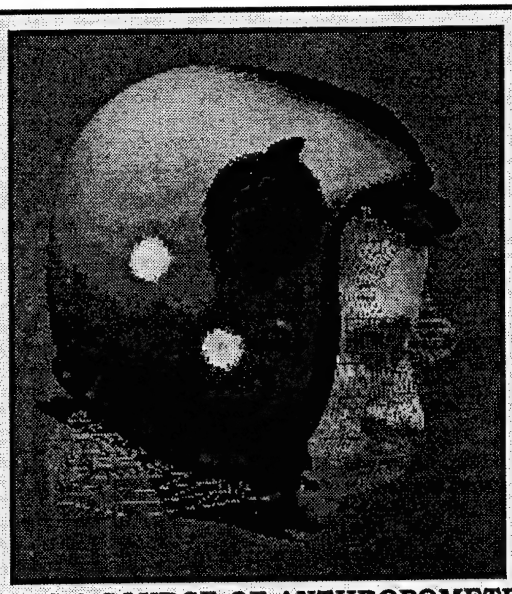


DEVELOPING TOOLS FOR COCKPIT DESIGN AND EVALUATION

Dr. Joe W. McDaniel working in the Crew-Centered Automated Design System Laboratory developing a suite of computer tools to assist in the design and evaluation of aircraft cockpits. The work is still in progress in 1994, although this picture was taken in 1993. (Project 2829)



FIT AS A SOURCE OF ANTHROPOMETRIC VARIATION

Three-dimensional geometric scans of two pilots, one a surface model and the other lines, aligned by the HGU 53/P helmets they wear. This illustrates the wide variation in the way equipment is worn, a variation which is often wider than the variation in the body size and shape of the population. (Workunit 71840846)

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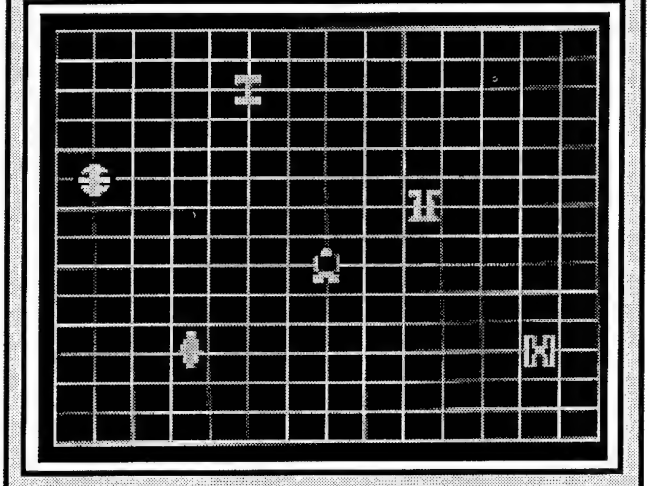

USING A DYNAMIC GRIDBOARD TO MEASURE SITUATIONAL AWARENESS

A grid board with moving symbols used in a study rating measures of situational awareness. The work was done by Maj Martin L. Fracker of the Human Engineering Division and Sharon A. Davis of Logicon Technical Services, Inc. AL-TR-1991-0091 (1991) (Task 718414)

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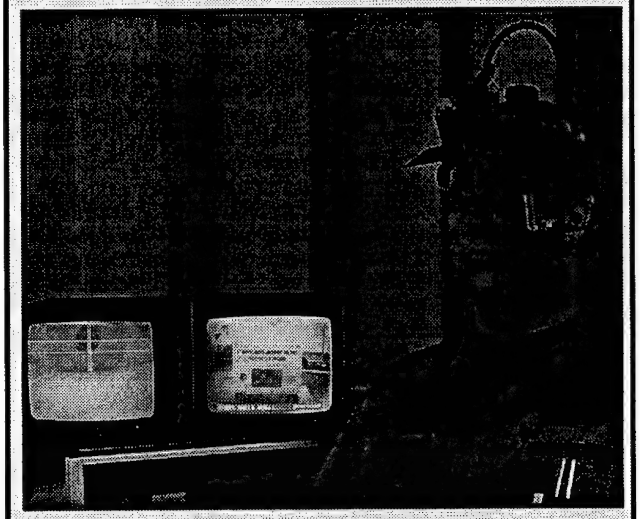

LINE-OF-SIGHT STUDIES

Lt Bryan Christensen is demonstrating a line-of-sight measuring system being used to study the direction of sight in helmet systems. This information is needed to optimize the design of helmet-mounted displays. (Workunit 71841158)

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A PROPOSED PANORAMIC COCKPIT FOR INCREASING SITUATIONAL AWARENESS

Panoramic cockpit control and display system (PCCADS 2000) developed in a program for increasing the situational awareness of pilots. This effort was jointly sponsored by AAMRL (AL/HEA) and the Wright Laboratory Cockpit Integration Directorate (WL/KTD). The work was done by John L. Olson, Christopher J. Arbak, and Richard A. Jauer of the McDonnell Douglas Corp. AL-TR-91-0017 (1991)

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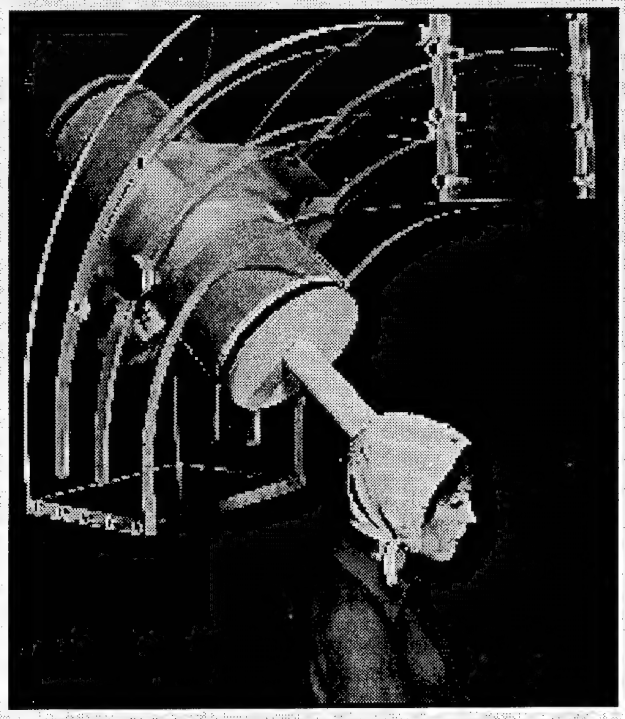

MEASURING MAGNETIC FIELDS IN THE BRAIN OF A STRESSED SUBJECT

Ms. Penny Fullenkamp serving as a subject in a stressful task while the locations and intensities of magnetic fields in her brain are measured by the SQUID electronics of a magnetoencephalography (MEG) device. This work is one of a series of investigations of psychophysiological measures of operator workload started by Dr. Glenn F. Wilson. Information about the MEG and other methods for assessing operator workload is available in Dr. Wilson's review of progress in the psychophysiological assessment of workload. AL-TR-1992-0007 (1992) (Task 718414)

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Researchers in the department today also use computers to help them develop workplace layouts and equipment designs. In fact, computers have produced "a revolution in systems designs," said Bates. "We have tremendous potential from high-speed computers and miniaturization of computer equipment that allows us to do things aerodynamically that we couldn't before because of the instability of some airframes. The engineer now has incredible design options for the way in which he interfaces the pilot with the airframe and the avionics on the airplane."

— C. Bates, May 1985, "Human Engineering, Yesterday and Today," Civilian Employees Reporter

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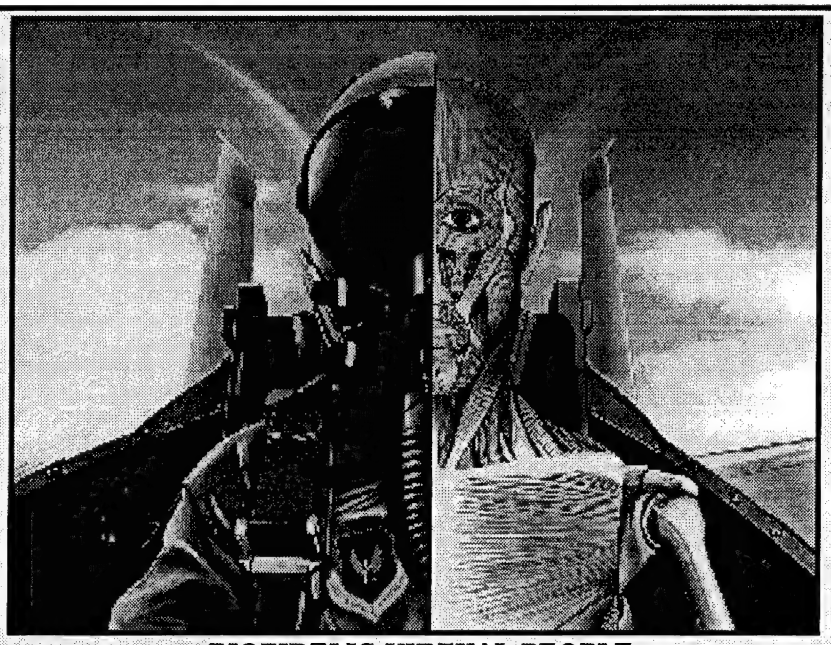

BIOFIDELIC VIRTUAL PEOPLE

An illustration depicting future life-like human models, referred to as "biofidelic" models, that will be used to design, test, and "try on" equipment within a highly graphic computer environment. The term biofidelic was coined by Mrs. Jennifer Whitestone. (Workunit 71840846)

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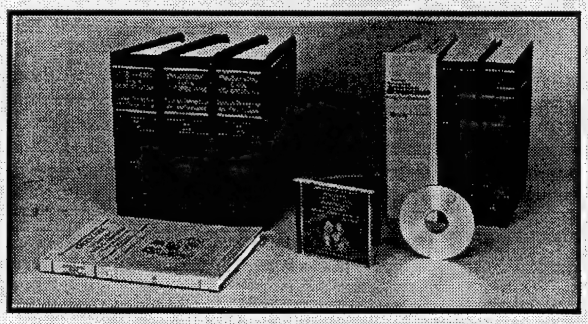

THE HUMAN ENGINEERING DATA COMPENDIUM

Engineering Data Compendium, Human Perception and Performance (1988), edited by K.R. Boff and J.E. Lincoln, an extensive three-volume, in-depth treatment of the basic data on perception and performance (also shown on CD-ROM) for use by the human engineering specialist and an efficient basis for access to the research literature. The figure also shows the primary reference for the Compendium, the two-volume "Handbook of Perception and Human Performance" (1986). These volumes are a unique source of data for guiding trade-offs between the characteristics of humans and machines in designing efficient man-machine systems by fitting the machine to its human users. (Workunit 71842607)

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ADVANCED NIGHT VISION GOGGLES RESEARCH

Mr. Pete Marasco evaluates the latest high-tech night vision goggle (NVG) system capable of displaying a 45-degree intensified field-of-view on optical combiners. (Task 718418)

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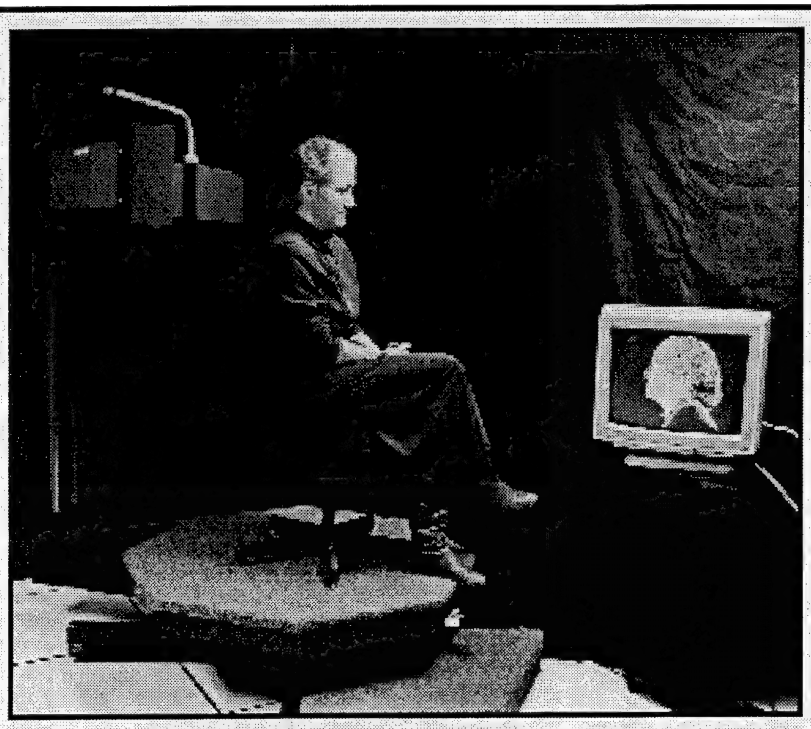

LASER SCANNING A HUMAN HEAD

Ms. Kathleen M. Robinette being surface scanned by a laser scanner which provides high-resolution surface data of her head and face. Her surface features are displayed on the computer graphics terminal. Laser scanning has advanced anthropometric methods at the Computerized Anthropometric Research and Design (CARD) Laboratory of the Human Engineering Division. (1993) (Task 718408)

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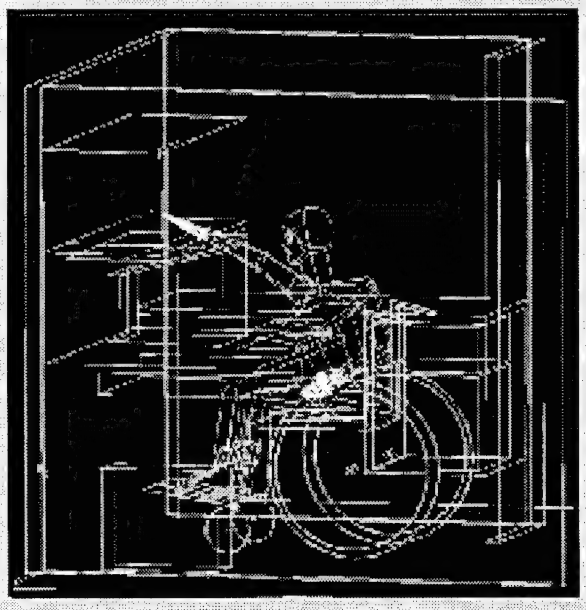
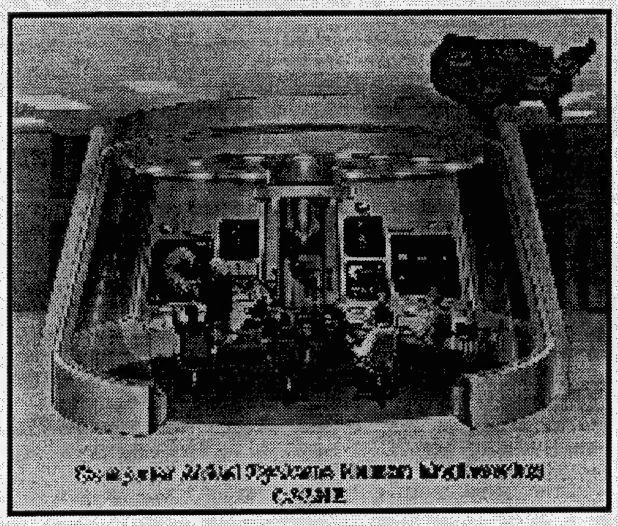


MODIFY WORKPLACES FOR THE PHYSICALLY DISABLED

The COMBIMAN computer model was used to evaluate the physical accommodation of a physically disabled woman in 1993. This proof of concept led to the development of a new program to help modify workplaces to accommodate disabled persons.



CASHE VISION

This Computer-Aided Systems Human Engineering (CASHE) vision shows a multi-disciplinary design team working with a CAD/CAE system in which ergonomic data is a "full partner" among other disciplines within the working environment. The combined use of integrated CRTs, small group wall displays, auditory systems, and virtual display technologies allows designers to fully visualize and experience the operational impact of the crew system design, even in its early conceptual design phase. All team members can interactively communicate their design proposals and solutions to other centers in this distributed design network.

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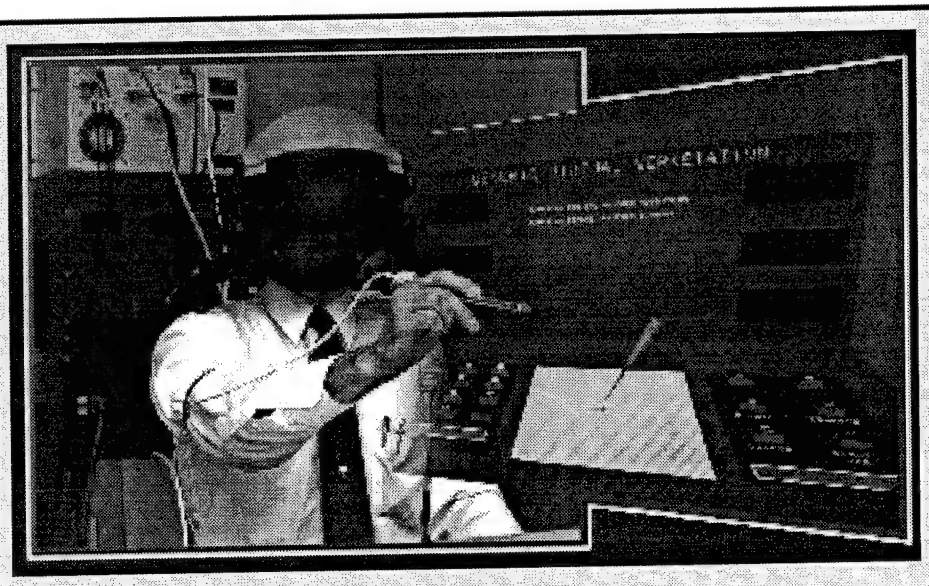

VIRTUAL WORKSTATIONS
Bill Janson who works with Dr. Robert Eggleston in the Virtual Environment Interface Laboratory (VEIL) is pointing the way to virtual reality!

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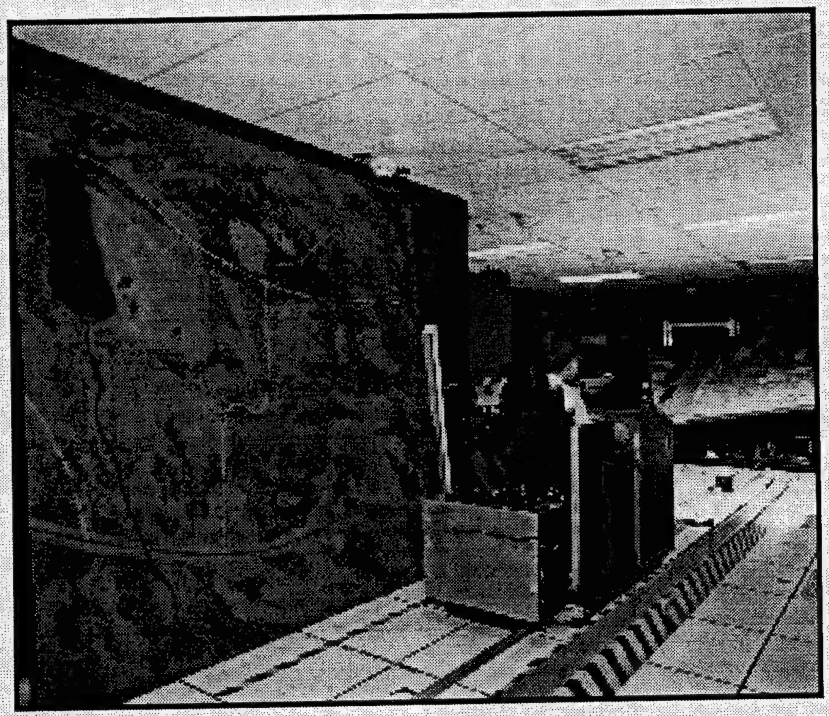

TERRAIN BOARD IN A STUDY OF DECEPTION TECHNIQUES FOR AIRBASE PROTECTION

An observer approaching a terrain board containing an airbase in a study of the effectiveness of deception using aircraft silhouette patterns on the ground. The work was done under Workunit 68930130, "Deceptive Technique Design and Evaluation" for the Subsystem/ Support Equipment Special Project Office (ASD/ANG). The work was performed by Capt Robert Kang of AAMRL and Joseph Riegler, George E. Irvin, and Luan Katz of Systems Research Laboratories. AAMRL-TR-87-023 (1987)

TASK TIME ESTIMATOR

SSgt Wiley Wells (CFHA) was a subject for researcher Glenn Severt of UDRI in a 1994 study of how obstacles lengthen the time required to complete assembly tasks. These data were for the new Task Time Estimator for the CREW CHIEF computer model.

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BRAIN ELECTRICAL ACTIVITY
Brain electrical activity determines the pattern of active brain areas used to solve complex problems. This information is used to understand human cognition and will help measure operator state. (Task 718414)

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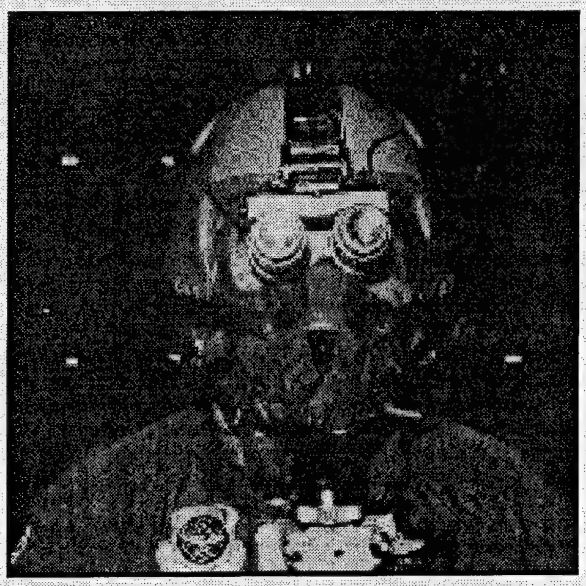
USING THE COPE WORKSTATION

2d Lt Suzanne Kelley using the Advanced Integrated Command, Control, Communication and Engineering Workstation of the C³ Operator Performance Engineering (COPE) task developed by the Human Engineering Division to study crew performance at command stations. This task was under the direction of Donald L. Monk and Michael D. McNeese. The picture was taken in 1986. (Project 7184)



PROTECTIVE HOOD AND NIGHT VISION GOGGLES

A chemical protective hood mask and aviator's night vision goggles used in a study to examine their compatibility. The work was conducted under Workunit 71841807 by Dr. Joseph T. Riegler of Logicon Technical Services, Inc. and Mary M. Donohue-Perry of the Human Engineering Division. AAMRL-TR-90-031 (1990)

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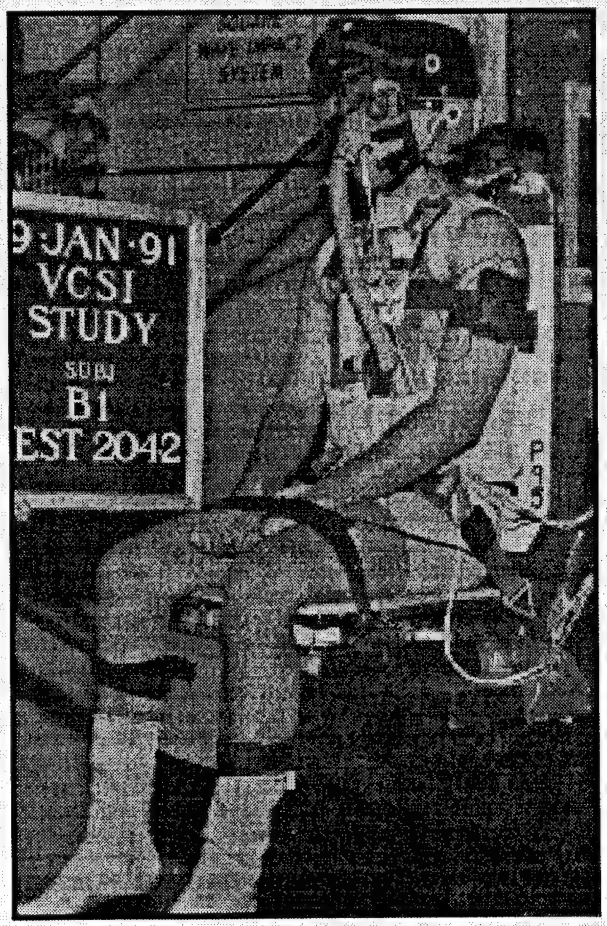
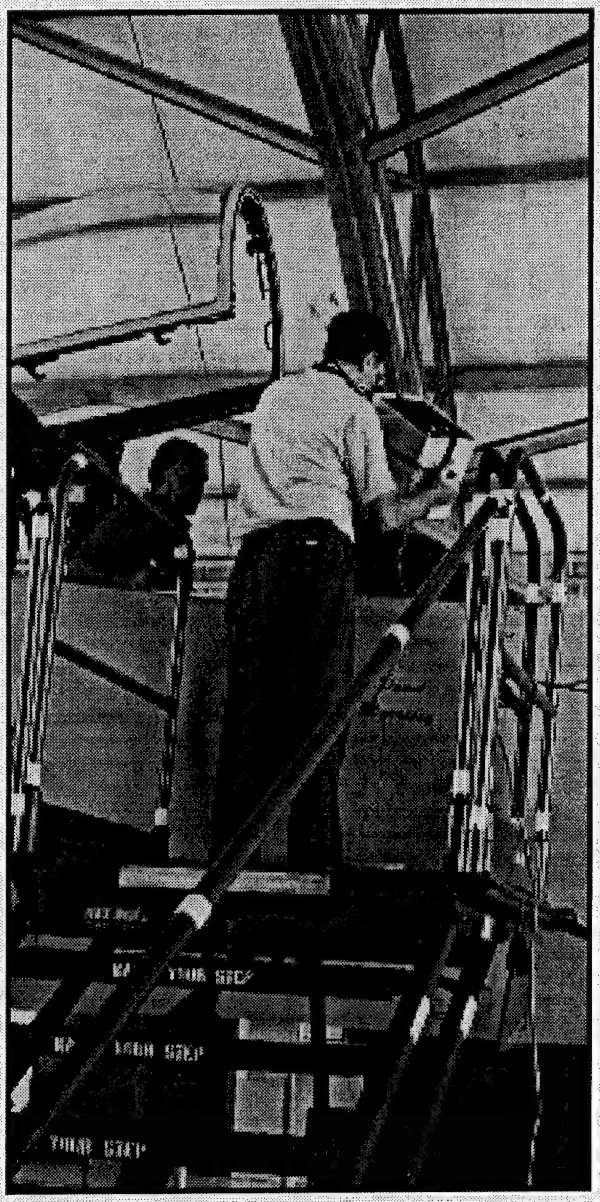


SIMULATING AIRCRAFT EJECTION FORCES FOR EFFECTS OF NIGHT-VISION GOGGLES

Seated test subject in a ground test vertical deceleration tower (VDF) for simulating forces occurring in ejection from aircraft in a study of integrated night vision goggles and a head tracking system. This is Volume 1 of a report prepared by R. Gunderman and J. Stiffler of Ball Systems Engineering Division for the Helmet Mounted Sensory Technology Project. AL-TR-1992-0087 (1992)



EVALUATING REFURBISHED AIRCRAFT WINDSCREENS

Lee Task (standing) and Bill Kama check out the condition of a refurbished F-15 windscreen at Eglin, AFB, Fla. (Workunit 71841802)

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Pilot's helmet helps interpret high-speed world

(New York Times—John Noble Wilford)

The pilot sits in the cockpit wearing a dark, bulging, bug-faced helmet that makes him look like the sinister Darth Vader in the movie "Star Wars." Projected on his visor is a synthesized panorama of the world he is flying over and into, the terrain below and the skies around. It is like having his head inside a marvelous, action-packed video game.

But it just may be the only way pilots will be able to handle the complex, high-speed aircraft of the future, especially in combat. Assisted by computers, tiny video tubes and other electronics, they will almost literally carry all their cockpit controls in the helmets they wear. The engineers who are developing this advanced technology call it a "virtual cockpit" or "supercockpit."

Missiles Streak Across Helmet Visor

On the helmet visor, the pilot sees moving green lines streak before his face, calling attention to antiaircraft missile fire. He applies pressure to the stick and makes a sharp evasive maneuver, away from the line of fire. The panorama, 120 degrees wide and 60 degrees high, changes accordingly. The pilot swings his head left or right and the view changes each time.

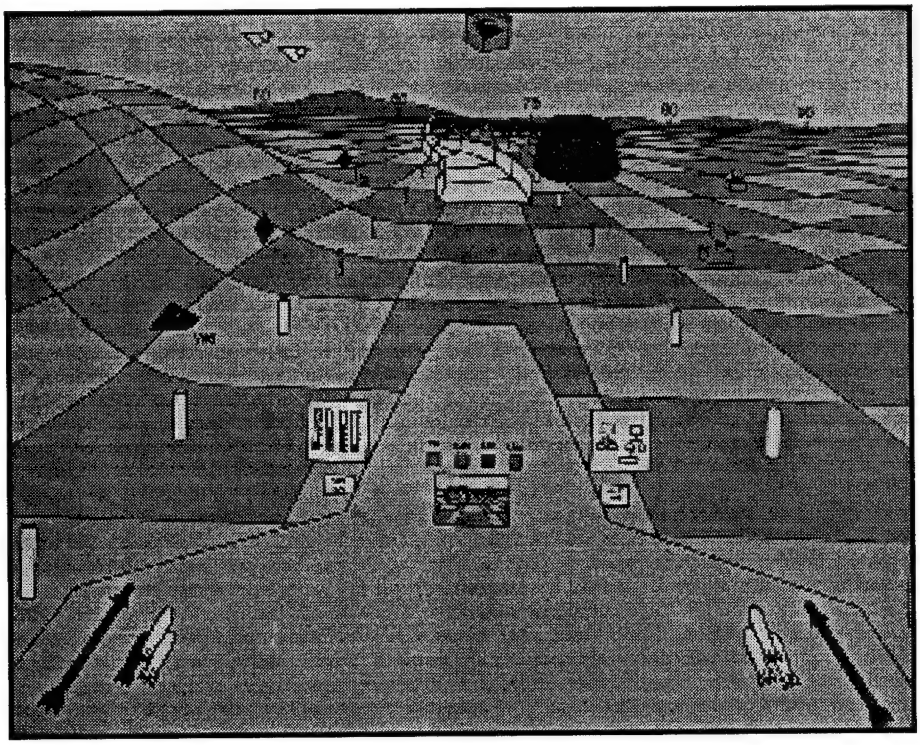
Superimposed on one corner of the panorama are numerical readouts of his altitude, velocity, and heading. There is a small square marked "status." He looks straight at the square, says "select" and sees projected there for a few moments symbols indicating the status of the plane's fuel, oil pressure and temperatures. The purpose is to know what he needs to know when he needs to know it, and not be overwhelmed by panels of gauges and dials.

Voice Commands Dispatch the "Bad Guys"

Ahead, above the outline of a distant mountain, appears a green triangle, topped by the number 9. Radar has detected a "bad guy" nine miles away. The pilot checks his weapons, calling by voice command for a symbolic display of the missiles available under the plane's wing. He selects one, by voice or by pressing a button, and the symbol for the selected missile flashes to remind the pilot it is ready.

The pilot wants a better view. "Zoom," he says, and an electronically synthesized voice echoes the command in confirmation. Instantly, the computer provides a closeup image of the terrain ahead, and of the bad guy. Or the pilot says "god's eye," and hears his command repeated. This, in effect, takes the pilot out of the aircraft and high above for a view of himself, the approaching enemy, and the entire theater of impending battle.

With a "normal" image put back before him, the pilot points the plane so the reticle of his gunsight rests squarely over the triangle marking the location of the enemy craft. He gives the command "lock on." Then, "fire." The missile streaks toward the target. A symbolic explosion of light fills the triangle in the image. An enemy is destroyed.



SYNTHESIZED PANORAMA PROJECTED ON VISOR OF FUTURE PILOT

Conceptual representation of the Super Cockpit in which the pilot has an abstracted pictorial view of the task, mission and threat environments. Night is turned into day, available weaponry are pictorially represented and accessed by alternative controls (voice, eye line-of-sight, or brain actuated). The pilot may navigate along a "highway in the sky." Threats are represented by their zones of lethality. (Workunit 71842601)

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NEW SIZING METHODS

Ms. Kathleen Robinette is demonstrating the fit of one off-the-shelf size from the new sizing system she helped develop for the Navy women's uniform. This sizing system reduced the need for alterations from 75% to less than 1% without increasing the number of sizes. (Workunit 71840850)

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MEASURING VISUAL OBSCURATION BY A HELMET AND OXYGEN MASK

Ms. Rebecca Unger is assisting TSgt Robert L. Stewart as he serves as an experimental subject in a study measuring the amount of visual obscuration caused by a helmet and oxygen mask. This work provided a small part of the data for the CREW CHIEF Man Model being developed by the Human Engineering Division. (1992) (Workunit 71840847)

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Another current project is space vision research, which the Air Force is working on with NASA. This consists of a series of tests being run on the space shuttle to determine the effects of microgravity on astronauts' vision. Astronauts have commented on changes in their vision in space, ranging from experiences of super vision to degraded near-vision.

—May 1985, "Human Engineering, Yesterday and Today," Civilian Employees Reporter

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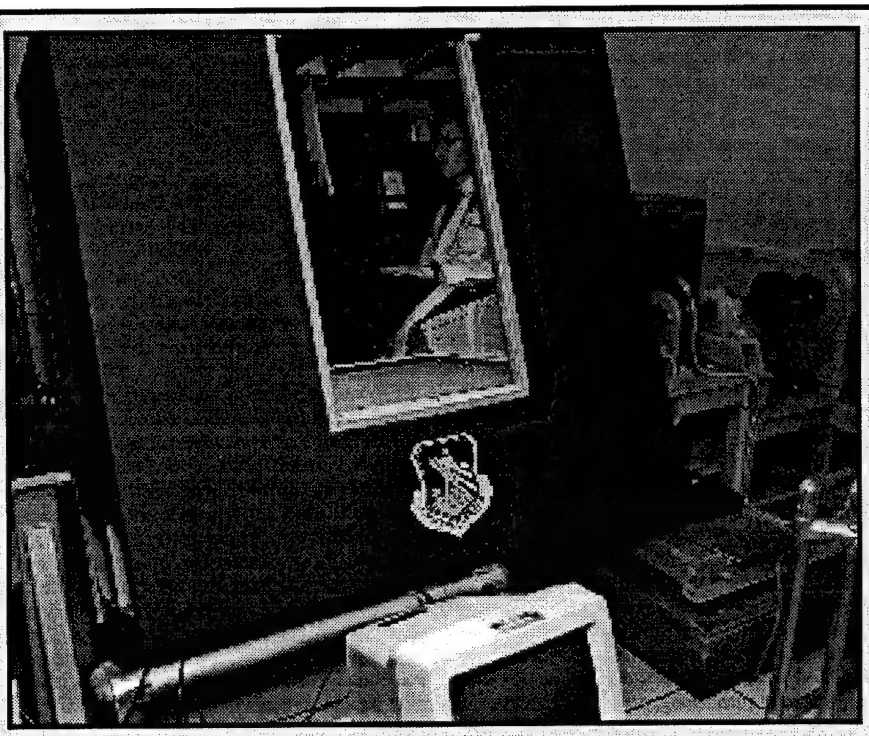

BRAIN ACTUATED CONTROL OF MOTION SIMULATOR

Dr. Paul Morton self-regulates his brain electrical activity to control the cab's roll position in the Alternative Control Technology (ACT) Laboratory. Specific patterns of brain electroencephalographic (EEG) activity are identified and monitored. Using a biofeedback training method, operators learn to enhance or reduce brain electrical response strength. Noninvasive scalp electrodes are used to record changes, which are then translated into commands that control the operation of a physical device or computer program. (1994) (Task 718414)

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RESEARCH TO DEVELOP A HMD SYMBOLOGY STANDARD FOR TACTICAL APPLICATIONS

Dr. Robert K. Osgood, Task Manager of the Tactical Aircraft Cockpit Design and Evaluation Program (Task 718426) and member of the Visual Display Systems Branch, evaluating several candidate helmet-mounted display symbology sets in an operational mission environment using the Visually-Coupled Airborne Systems Simulator (VCASS). Osgood won the first Crew Systems Directorate Scientific Excellence Award in 1992 for his work in this research domain.

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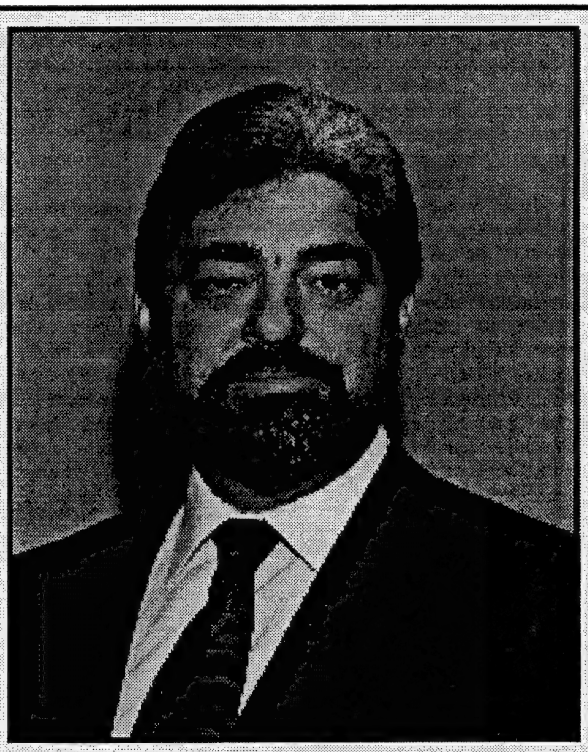
Kenneth R. Boff, PhD
Chief, Human Engineering Division

April 1991 to Present

The current Chief of the Human Engineering Division, Kenneth R. Boff earned a PhD in experimental psychology (Dynamic Visual Performance) from Columbia University in 1978. His personal research has focused on facilitating applications of human performance data and models in the design and evaluation of complex human system interfaces. More recently, he initiated the development of innovative data visualization techniques to enable computer-aided design, or CAD, representation of human performance data for crew system designers.

Dr. Boff actively consults and provides technical liaison with a broad range of government agencies, international working groups, universities, and professional societies and is founder and Technical Director of the Crew System Ergonomics Information Analysis Center (CSERIAC). He is the United States' Principal Investigator for the Joint US-French Super Cockpit Technologies Program, and an appointed member of the AGARD Aerospace Medical Panel, within which he chairs the Human Factors Committee.

Holder of a patent for Rapid Communication Display Technology, Dr. Boff has authored numerous articles, book chapters, and technical papers and is co-editor of *System Design* (1987), Senior Editor of the two-volume *Handbook of Perception and Human Performance* (1986) and the four-volume *Engineering Data Compendium: Human Perception and Performance* (1988).



Beginning in 1993 Dr. Boff served as the Joint Services Working Group Chairman leading the effort to establish the Human Systems Interface (HSI) technology area within Joint Directors of Laboratories (JDL) Reliance. In April 1994, the HSI Panel was formally approved within the Department of Defense and Dr. Boff was appointed Panel Chairman.

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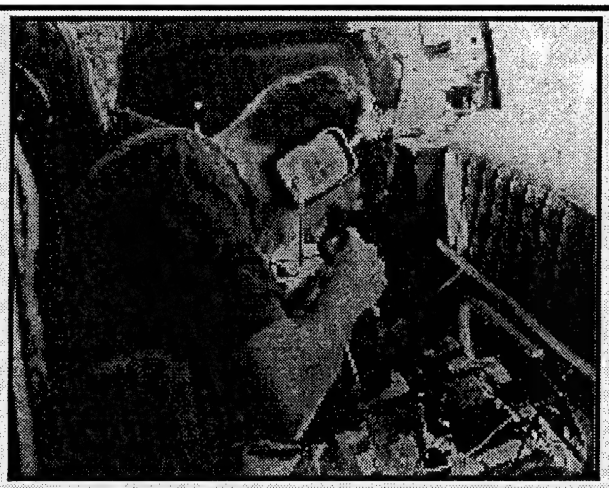

USING AN OPTICAL VIEWING SYSTEM TO FIND GROUND TARGETS

An airborne observer visually searching for a ground target with a direct-view optical system in a target detection study measuring the usefulness to observers of briefing aids. The work was done under Program 62202F, Project 6893, Task 11, Workunit 02 by Lt Harold S. Merkel and Harry Lee Task. AAMRL-TR-87-026 (1987)

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FUSION INTERFACE FOR TACTICAL ENVIRONMENTS (FITE)

Developed by Michael Haas in 1992, FITE utilized 25 personal computers to create a simulated, multi-aircraft air-to-air combat environment including aerodynamic, avionics, and weapons models. The crew station concepts and symbology developed in the FITE integrated helmet-mounted displays, 3-dimensional auditory display, head-up/head-down displays, and haptic displays. (Task 718419)

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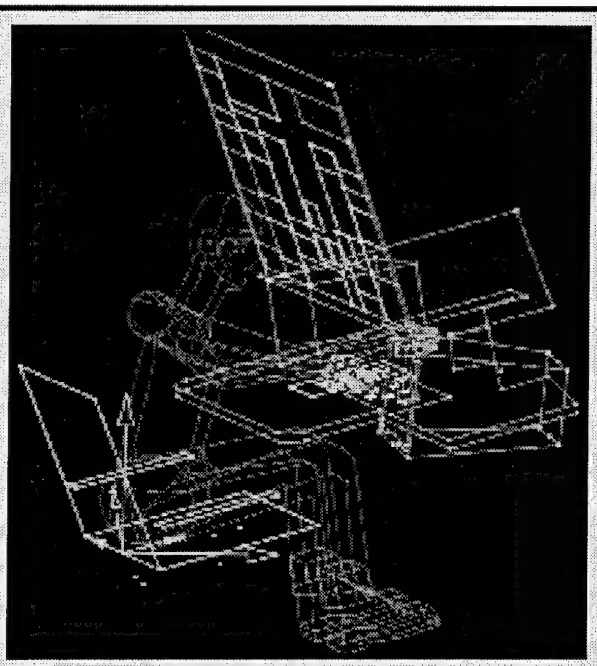

COMBIMAN IN THE C-141

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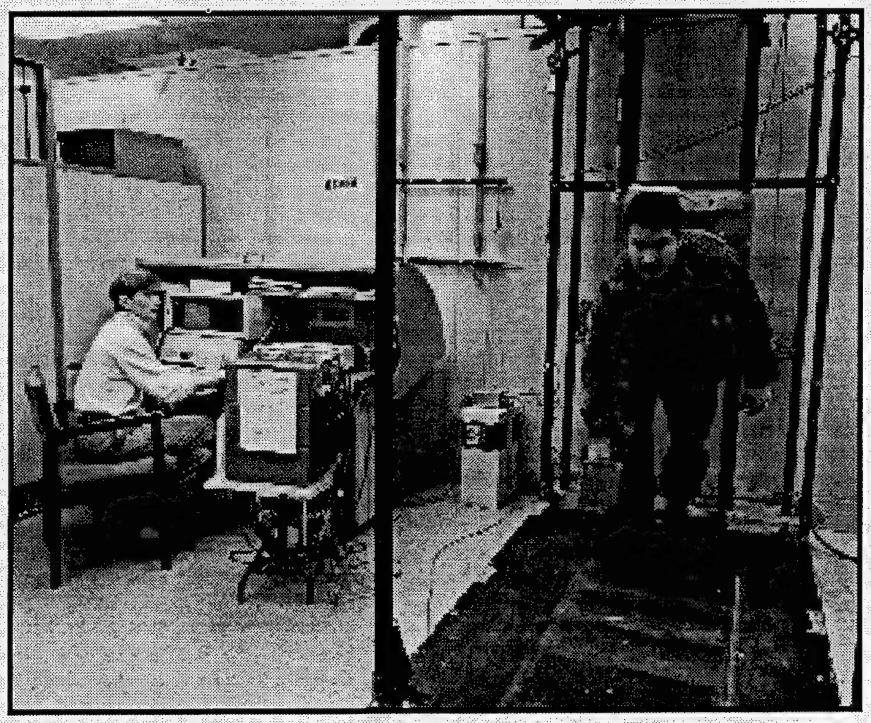
POSTURE FOR LOAD CARRYING

SSgt Wiley Wells (CFHA) was a subject for researcher Becky Unger of UDRI in a 1994 study on posture for load carrying. Work posture is determined by a combination of factors, including the low ceiling and the amount of weight carried in the hands. (Task 718408)



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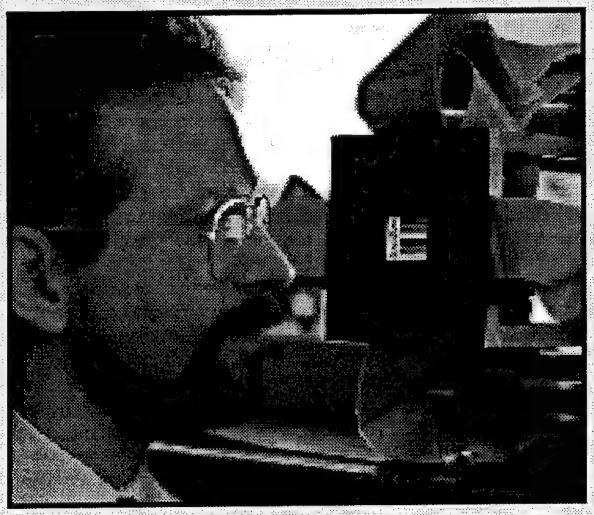

COLOR HELMET-MOUNTED DISPLAYS

Dr. David L. Post examines the Miniature Color Display (MCD), developed in 1993 by the Color Display Laboratory for airborne helmet-mounted displays. This breakthrough device has laser-printer resolution and 100 times more light than a TV. The technology has been transitioned to the Advanced Research Projects Agency for advanced development. (Workunit 71841149)

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WINDSCREEN RESEARCH
An F-111 windscreen undergoes optical distortion analysis in preparation for a visual assessment study. (Task 718418)

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"Some of my most satisfying work was the refinement of the brain stem evoked response as a screening method for detecting hearing deficits in young children. A pediatrician and a neurologist at the Base Hospital picked up on this and used to send kids—and later adults—over to us at the lab for testing. At one time we had 3 to 4 patients a day being transported over there; we must have tested a total of 200 to 300 people. Real medical decisions were being made on the basis of this test. It's interesting that most audiologists at that time were negative about the use of the evoked brain stem technique. Well, I just had my hearing tested at the Base Hospital recently and asked if they ever do brainstem evoked response. The audiologist said, 'Oh yes, that's our standard procedure.'"

— Robert O'Donnell, Chief
Workload and Ergonomics Branch
Human Engineering Division

"One of the last efforts I was involved with here was dramatically different from any other I had done, but was very enjoyable. It had to do with the design of checkout counters for the commissary system. Since checkout personnel come in all sizes, there was a need to develop a counter which was either a good compromise height for everyone, or to come up with an adjustable version, so that repetitive motion injuries could be avoided."

— Steve Heckart
Applications Human Engineer
Human Engineering Division

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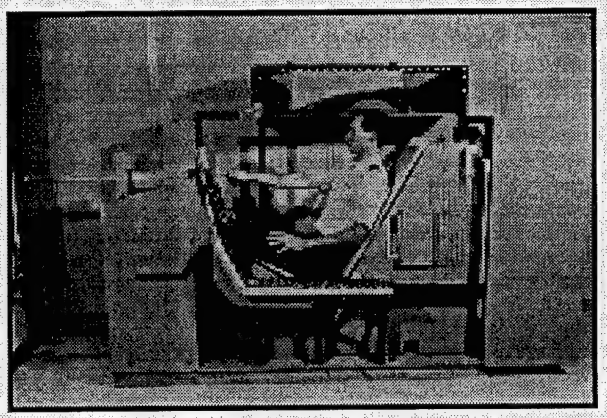

TESTING A PILOT'S REACH IN GEOMETRY COCKPIT

Testing a subject's reach in cockpits with low profiles and variable cockpit geometry. This study was done under Task 718404, "Crew Station Design and Techniques" and Workunit 71840835, "Engineering Anthropometry for Systems and Subsystems Design" by Kenneth W. Kennedy. AAMRL-TR-86-016 (1986)

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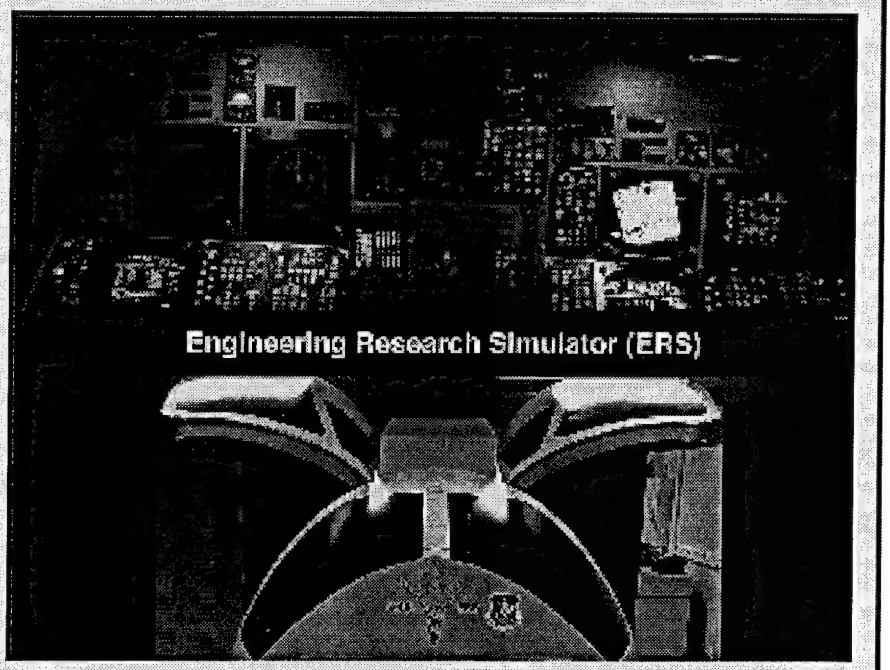

OPERATIONAL RELEVANCE

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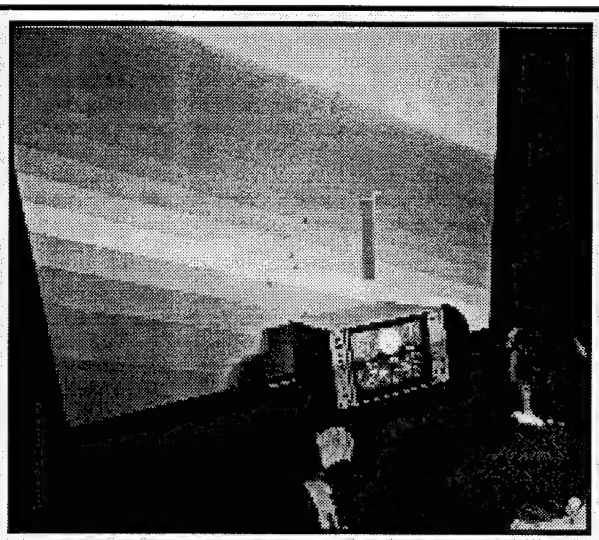
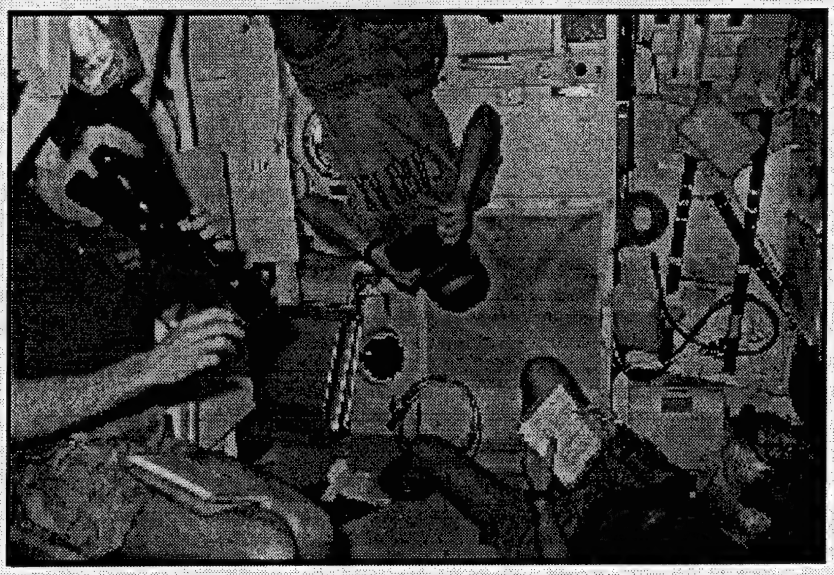


PACLAF LOOKS AT VISUAL SAFETY CUES

High-speed, low-altitude flight over rolling terrain is difficult, especially in sparse desert environments. PACLAF, managed by Dr. Rik Warren, investigates the visual cues pilots need to safely accomplish their mission. Here the effects of texture density and a supplemental altitude display are assessed. (Task 689306)



TESTING VISION IN THE SPACE SHUTTLE

Astronauts in orbit around the Earth on Space Shuttle flight STS-36 undergoing vision tests with the Visual Function Testers VFT-1 and VFT-2. This was part of a space vision study conducted by Harry L. Task, Lt Col Mel O'Neal and Col Louis V. Genco of the Human Engineering Division. (1990) (Task 689311)

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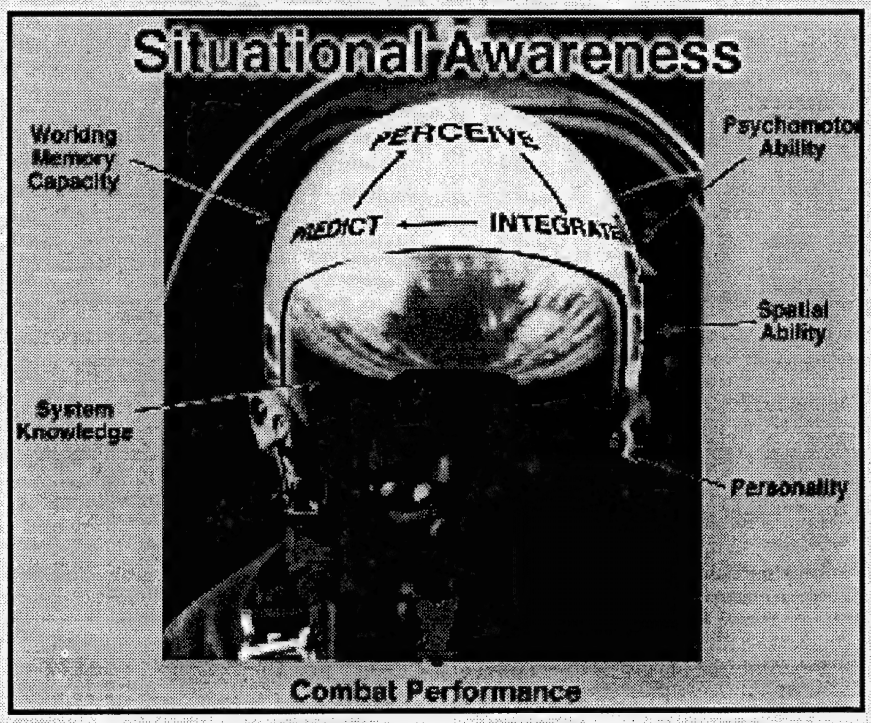

PILOT SITUATIONAL AWARENESS CRITICAL TO COMBAT SUCCESS

Pilot Situational Awareness involves the continuous perception and integration of information and the prediction of future events. Many factors contribute to good situational awareness, including personality, cognitive abilities, and training. (Task 718414)

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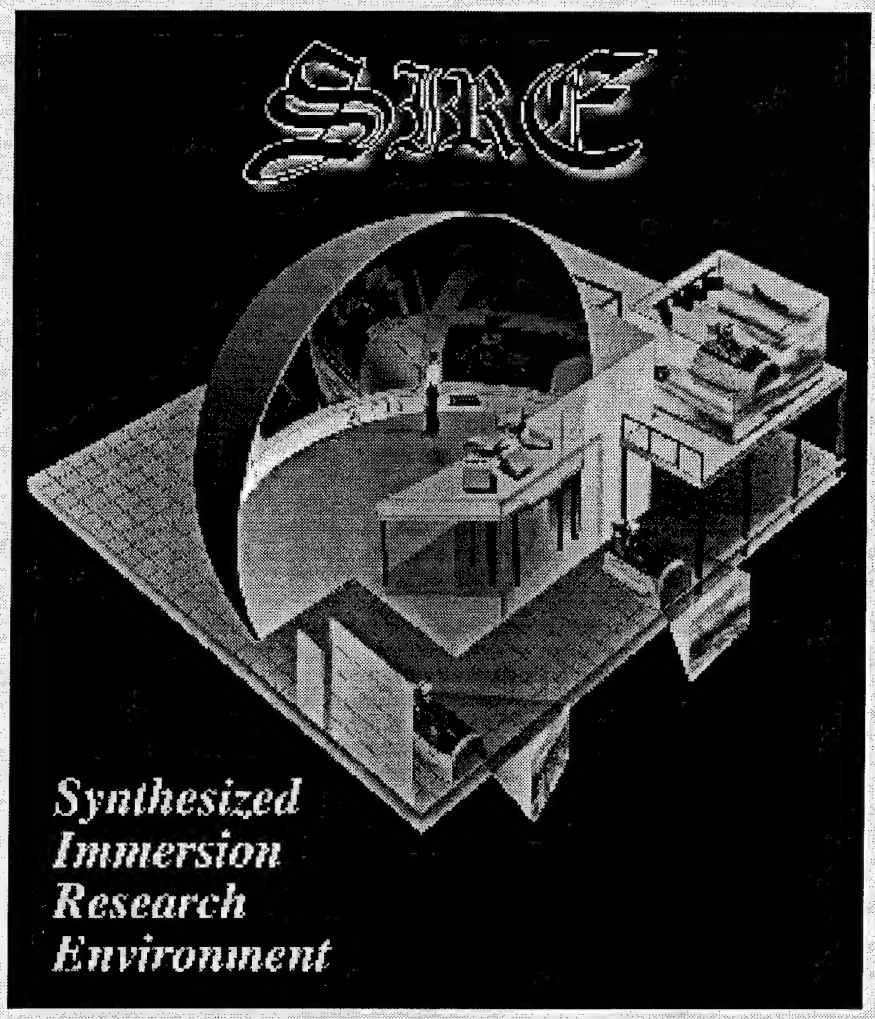

SYNTHESIZED IMMERSION RESEARCH ENVIRONMENT (SIRE)
The Synthesized Immersion Research Environment (SIRE) became operational in 1994 and supported the integration and assessment of multi-sensory, virtually augmented human-system interface concepts. SIRE included several autonomous research stations, the largest of which was a 40-foot diameter spherical projection surface linked to a general-purpose Silicon Graphics Onyx graphics generator supporting scientific visualization and multi-sensory research. (Task 718419)

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"The research emphasis at the lab has shifted over the years. When I first got there, we were still really focused in on 'knobs and dials' — the classical applied human engineering concerns. But, after struggling with constructs like 'workload,' I believe the emphasis moved in the direction of cognitive psychology. From my admittedly biased perspective, I see human factors moving more in the direction of the cognitive and neuropsychological sciences. People who get into human factors research now are educated much more in the cognitive areas than previously. They are attacking more complicated problems like situation awareness, workload, and so forth. I think that's where the breakthroughs will come."

— Robert O'Donnell, Chief
Workload and Ergonomics Branch
Human Engineering Division

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"The seat in the F-16 had been reclined to 30 degrees due to the raised heel rest line which was designed to accommodate for the air intake under the plane's belly. But the F-16 Program Office advocated that the increased recline angle of the seat would also improve G tolerance. Pilots reported increased ability to tolerate high Gs with this seat; however, we found this anecdotal evidence was refuted by subsequent centrifuge data, and it was thought that the pilot's perceptions of increased G tolerance were just a reflection of the improved comfort of the reclined seat. That is, they were more comfortable, but G tolerance was no better. We used centrifuge studies to test the effectiveness of different angles of seat recline, and a new database emerged providing valuable data on high G tolerance which still serves as a reference today."

— Phil Kulwicki, Technical Director Crew-Centered Cockpit Design Human Engineering Division

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